PHYTOPLANKTON ASSOCIATIONS IN LAKE ONTARIO DURING IFYGL

EUGENE F. STOERMER and THEODORE B. LADEWSKI

Great Lakes Research Division
The University of Michigan

Grant NOAA-04-4-022-32

Project Officer

ANDREW ROBERTSON
Great Lakes Environmental Research Laboratory
National Atmospheric and Oceanic Administration
Ann Arbor, Michigan 48104

Special Report Number 62
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan 48109

1978

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ABSTRACT

During the International Field Year for the Great Lakes (IFYGL, June 1972-June 1973), phytoplankton samples were taken from a network of stations covering the offshore waters of Lake Ontario at approximately monthly intervals. Association analysis was performed on data from near-surface samples using principal components analysis (PCA) in an attempt to determine if regions of floristic similarity were present which might prove useful in developing appropriate segmentation for modeling of the system. Results of the analysis showed a general pattern of community similarity on a yearly basis, but generally weak associations and poor spatial coherence during a single sampling period. It appears that phytoplankton assemblages in a highly perturbed system such as Lake Ontario undergo rapid and complex responses to environmental forcing functions, which are not adequately resolved by monthly sampling. As might be expected, association differentiation in the surface waters is strongest during periods when strong physical gradients are present (spring warming). An analysis of the trend in abundance of some important taxa with respect to temperature is provided.

ACKNOWLEDGMENTS

The authors wish to express appreciation for the work of Marybeth Bowman and John Kingston, who performed the taxonomic analysis of the phytoplankton slides. The tedious job of calculating cell volumes for hundreds of taxa was done by Marybeth Bowman. Assisting in sample collection and preparation aboard the R/V Researcher and R/V Limnos were Nancy McLean, Wendy Moore, Jim Kubus, Andrew Schaedel, Ken White, and Don Willis.

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INTRODUCTION

A major objective of the IFYGL Lake Ontario field study was to obtain a data base for a subsequent modeling effort. A part of this model would of necessity deal with the lake's phytoplankton communities. However, a complete characterization of the phytoplankton by any model is at present impractical. In a study of IFYGL near surface water samples (Stoermer et al. 1974), 297 phytoplankton taxa were enumerated, and no model can currently handle that many entities. In addition, the IFYGL project studied 60 stations in Lake Ontario and this many stations likewise poses problems for modelers. One solution to these problems is to reduce the number of taxonomic entities by identifying natural groupings of these taxa and similarly to group the 60 sampling sites in Lake Ontario into a smaller number of regions within which the phytoplankton community is reasonably uniform. Thus, this paper will attempt to answer two basic questions: Are there any groups of phytoplankton which tend to be found at the same place at the same time? Can the lake be segmented into regions, each with its own characteristic community?

This report presents an attempt to characterize the complex and dynamic phytoplankton communities of Lake Ontario during IFYGL in a simple yet meaningful way. The method used is principal component analysis (PCA), a multivariate technique currently in rather common use to describe community structure (e.g. Orloci 1966). Each of the 10 IFYGL cruises is analyzed separately. Two analyses are presented for each cruise: one using carbon density of phytoplankton taxa (equivalent to an analysis of cell density, as discussed below) and a second using the estimated fraction of total algal carbon contributed by the taxa. Each of these analyses provides two complementary views of the data. The first is a segmentation of the lake into regions each with its own phytoplankton community. The second is a grouping of taxa into communities which are found in these regions.

In addition to the PCA and associated analysis of spatial distribution of phytoplankton, a summary description of the seasonal patterns of the major phytoplankton groups and their most abundant members will be given. Also a parameterization of the occurrence of important taxa with respect to temperature is given.

MATERIALS AND METHODS

Samples used in the analyses were collected with Niskin bottles from water 1m below surface. Phytoplankton samples were fixed with gluteraldehyde (4% by volume). A 50ml subsample was then filtered through a 25mm "AA" Millipore filter and mounted on a slide with beechwood creosote. Slides were counted visually using a Leitz Ortholux microscope fitted with fluorite oil immersion objectives giving approximately 1190X magnification and nominal Numerical Aperature of 1.32. Each slide was scanned to count cells to species level from 0.48 ml of lake water. For further description of the species enumeration and collection procedure see Stoermer et al. (1974).

Raw phytoplankton counts are then used to calculate for each taxon i:

a) cells/ml = D_i

b) µg carbon/1 = C_i

c) fraction of total algal carbon = $C_i / \sum_{j=1}^{N} C_j = P_i$

where N = total number of taxa.

Ci is calculated from D_i using equations given by Strathmann (1967) for pg carbon/cell:

for diatoms, $\log c_i = .758 \log V_i - .422$; SE=.198

for other phytoplankton, $\log c_i = .866 \log V_i - .460$; SE=.110

where c_i is pg carbon/cell, V_i is the volume of one cell of taxon i, SE is the standard deviation of the estimate for log C_i, and log is taken to base 10. Cell volumes for each taxon are taken from averages made from original specimens counted for IFYGL. V_i represents an average of up to 15 volume measurements for common taxa. The values for C_i are calculated as:

$C_i = c_i * D_i \ / \ 1000.$

Analytical Methods

The data for the 1m samples from a cruise were analyzed using principal component analysis (PCA). Briefly, this technique is a type of cluster or association analysis. It shows in an approximated way the degree of similarity or dissimilarity between samples with respect to the phytoplankton taxa found in those samples. Simultaneously, it determines the degree of similarity and dissimilarity between the phytoplankton taxa with respect to their distributions. Thus the analysis finds stations in the lake which have similar phytoplankton communities at the 1m sampling depth, and it determines which taxa belong to those communities. More complete descriptions of the technique are found in Orloci (1966) and Morrison (1967).

Two PCA were performed on the data from each cruise. The first analysis uses algal carbon density (C_i). The correlation matrix is employed, and thus this analysis can be viewed as using carbon density standardized to the taxon's

mean and standard deviation. This transformation to standard deviation units in effect removes the importance of a taxon's absolute abundance. Rare and common taxa have nearly equal impact on the results of the analysis. Another implication of the standardization is that, since scale is removed, the unit of measure is as well. This analysis of taxa density in µg-C/1 may therefore be considered to be equivalent to any other analysis of data proportional to carbon density. In particular, this analysis is identically equivalent to an analysis of taxa cell density (D_i). The second analysis uses the fraction of total algal carbon (P_i) to characterize the taxa. The variance-covariance matrix is employed, and thus no transformation to standard deviation units is performed for this second analysis.

Sources of Error

Both of these analyses are subject to errors from various sources. The most important source of error affecting the PCA on carbon density (or cell density) results from the limited number of cells counted for each taxon. For solitary cells, the standard deviation of the cell count will be n, where n is the number of cells counted. This results from characteristics of the Poisson distribution, which we have demonstrated to adequately describe the distribution of cells on the slides. Consequently, the fractional error for counting n solitary cells is $\sqrt{n}/n$ or $1/\sqrt{n}$. Thus, as more cells are counted, the relative error decreases. For n=10 the relative error is 32%, while for n=100 it is 10%. In this study the values of n for solitary cells is typically about 10, but can reach into thousands.

Many taxa are not solitary, however. Such taxa may form colonies from two or three up to many hundreds. For these taxa, it is not the number of cells counted but rather the number of colonies counted (as well as variability in colony size) which determines the relative error in the estimate of population density. For n_c colonies of equal size, the relative error in n will be $1/\sqrt{n_c}$ regardless of the number of cells actually counted.

The PCA, on fraction of total algal carbon, is subject not only to the source of error just described, but also to other sources related to the calculation of carbon density, C_i:

i) error resulting from the SE of the estimate of log c_i in Strathmann's (1967) equations. The SE for diatoms is 0.198. This SE for log c_i translates into an error in c_i of a factor of 1.58. The SE for other phytoplankton (.110) translates into an error of a factor of 1.29.

ii) errors resulting from variability in cell volumes. For some taxa, the variability between cells is small. For others, the average cell of a taxon may be 3X as big as the smallest cells of the taxon but only 1/3X as big as the largest. Although errors may be large in estimating the carbon of an individual cell, estimation of total carbon for a number of cells of a particular taxon will, in a relative sense, be lower since positive and negative errors will tend to cancel. Variability between the mean of the measured individuals and the population probably contributes an error of at most 20 - 50% to cell volume for most taxa.

iii) errors in measurement of cell volume. A change of only 26% in each linear dimension results in a factor of two change in volume. Thus, small measurement errors can result in large errors in calculated volume. (This problem is most severe for small cells.) In addition, calculation of cell volume requires the selection of a similar geometric form on which to base the calculation. Deviations from this assumed form contribute to errors in volume calculation. Taking ii and iii together, it is expected that cell volumes are accurate to a factor of two for at least 50% of all taxa. This factor of two is equivalent to an error of 0.3 in log V_i in Strathmann's equations.

iv) potential errors resulting from inappropriate application of Strathmann's equations. All taxa used in the determination of his equations are marine, whereas all taxa in this study are of freshwater varieties. Nalewajko (1966) gives ash-free dry weights and cell volumes for 28 freshwater phytoplankton. Twenty-one of these taxa were isolated from Lake Ontario. These data are plotted as ash-free dry weight *vs.* cell volume in Fig. 1. Assuming that cell carbon is 40-60% of total ash-free dry weight (e.g. Healy 1975; Vollenweider 1969) these data are seen to be consistent with the equations of Strathmann. Consequently it will be assumed that the Strathmann equations apply to the IFYGL phytoplankton data.

All above contributions to errors in cell carbon may be combined. (Add variances from independent error sources to get the resulting variance.) The SE associated with the regression (.198 and .110) and the estimated error in log V_i (about 0.3) combine to give errors for log C_i of 0.3 for diatoms and 0.28 for other types. This leads to the conclusion that estimates of cell carbon are probably accurate to within a factor of two for most taxa. The errors in estimating carbon density are large in an absolute sense, but not in a relative one. Cell carbon values range from 1 pg/cell to over 7000 pg/cell. Although carbon density estimates may not be accurate to better than a factor of 2, this error is small relative to the tremendous range of nearly four orders of magnitude for cell biomass, and thus conversion of cell density to carbon density provides a reasonable first attempt to compensate for differences in cell size.

Criteria for Inclusion in PCA

Several considerations must be made in choosing taxa to be used in a PCA. It is important to include as many taxa as possible in order to maximize the scope of the results and conclusions. However, interpretation of results is quite difficult if a large number of taxa is used. For a PCA using the correlation matrix, a list of taxa numbering from about 10 to 30 appears to be optimal for most phytoplankton data when the number of environment types represented in the samples does not exceed five and when three principal components are analyzed.

Further considerations involve abundance of the taxa. For PCA using the correlation matrix, locally or erratically occurring taxa often dominate results, and taxa counted in only small numbers have large associated relative errors which reduce the reliability and interpretability of results.

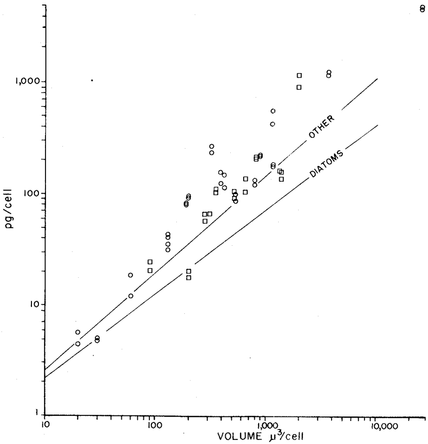

FIG. 1. Cell weight *vs.* cell volume. Ash-free dry weight data taken from Nalewajko (1966) are represented by squares for diatoms, circles for other types. The two regression lines are from Strathmann (1967) and show cell carbon weight as a function of cell volume for marine algae.

With these considerations, the following frequency of occurrence criteria were chosen for determining the list of taxa used in the PCA for a given cruise. For inclusion, a taxon must:

i) be observed at no less than 1/3 of all samples taken on any given cruise.

ii) attain at least 10 colonies (or individuals if solitary) in one sample. This criterion is relaxed to 8 colonies on cruises 5-8 due to the small population densities and low counts on all samples from these cruises.

A list of taxa used in the analyses is given in Table 1.

TABLE 1. Taxa used in the PCA's.

CODE	SPECIES or CATEGORY	Cruise number 1	2	3	4	5	6	7	8	9	10
ANKIFALK	*Ankistrodesmus falcatus*	X	X	X	X						X
ANKISEGI	*A. setigerus*				X						
ASTEFORM	*Asterionella formosa*	X	X	X				X	X	X	X
CRYPEROS	*Cryptomonas erosa*	X	X						X	X	
DIATTEVE	*Diatoma tenue* var. *elongatum*		X	X							X
FLAG#1	flagellate #1	X	X	X	X	X	X	X	X	X	X
FLAG#2	flagellate #2	X	X				X			X	X
GLENGYMN	*Glenodinium, Gymnodinium* spp.	X	X	X		X	X	X	X	X	X
GLOEPLAN	*Gloeocystis planctonica*			X							
LAGECILI	*Lagerheimia ciliata*				X						
MELOISLA	*Melosira islandica*	X	X							X	
NITZACIC	*Nitzschia acicularis*	X	X	X							X
NITZBACA	*N. bacata*	X	X			X		X	X	X	X
NITZDISS	*N. dissipata*	X	X						X	X	
NITZ#2	*N.* sp. #2	X							X	X	
OOCYSTIS	*Oocystis* spp.				X	X					
OSCIBORN	*Oscillatoria bornetti*										X
OSCILIMN	*O. limnetica*	X	X	X		X	X		X	X	X
PHACLENT	*Phacotus lenticularis*				X		X				
PERIDIN	*Perinidinium* spp.	X	X	X	X	X	X	X	X	X	X
SCENBICE	*Scenedesmus bicellularis*	X	X						X	X	X
SCENQUVS	*S. quadricauda* var. *quadrispina*				X						
STAUPARA	*Starastrum paradoxum*				X						
STEPALPI	*Stephanodiscus alpinus*	X			X	X	X	X	X	X	
STEPBIND	*S. binderanus*	X	X	X						X	X
STEPHANT	*S. hantzschii*	X	X	X		X	X	X	X	X	X
STEPMINU	*S. minutus*	X	X	X	X	X	X	X	X	X	X
STEPSUBT	*S. subtilis*	X	X	X	X	X	X	X	X	X	X
STEPTENU	*S. tenuis*	X	X	X		X	X	X	X	X	X
SURIANGU	*Surirella angusta*	X						X	X	X	
SYNEOSTE	*Synedra ostenfeldii*		X								X
ULOTSUBC	*Ulothrix subconstricta*				X						X
	TOTAL NUMBER OF TAXA USED	21	20	14	12	11	11	11	16	19	19

Interpretation of PCA Results

Following the PCA, samples (stations) are plotted relative to the scores on the first three principal components. Peripheral clusters are determined visually from the plot, and intermediate clusters showing the relationships between the peripheral clusters are determined. These steps require subjective decision, and results can vary somewhat depending on the judgement of the person determining the clusters. However, final results will, in general, be fundamentally the same.

The phytoplankton taxa are then plotted relative to their loadings. Clusters of taxa (communities) are determined from this plot. The plots of samples (relative to scores) and taxa (relative to loadings) are then compared to determine in which regions of the lake the communities belong. Conclusions are checked against the original phytoplankton abundance data for verification. A map showing the regions of the lake (locations of the stations in the clusters) is then drawn.

An analysis of variance assuming unequal sample sizes (Sokal and Rohlf 1969, p. 208) is performed for each taxon to determine if its abundance is significantly different between regions of the lake. For those taxa showing significance, the pattern of occurrence is determined from the ANOVA cell means.

NEAR-SURFACE PHYTOPLANKTON TEMPORAL PATTERNS

Table 2a shows mean values of cell densities for the major algal divisions for each cruise. Also shown is the weighted average of the cruise means to give an approximation to an average annual cell density. Cruise means are weighted to compensate for the irregular sequence of sampling. To account for the double spring sampling, all cruises are considered to have occurred during one 12-month sampling period. Thus, for example, the tenth cruise of 11-14 June 1973 and the second cruise of 12-16 June 1972 are considered to be two cruises taken in the same month of the same year. This averaging method assumes a cyclic phytoplankton pattern with a period of 12-months that has been verified by many investigators for Lake Ontario and the other Great Lakes. Also shown on Table 2a is the weighted mean of the total cell density and the mean percent of total cells contributed by each division. This percent is derived from the quotient of mean cell density for the division and mean total cell density. The divisions in Table 2a are ordered by annual mean abundance.

Table 2b shows cruise mean values for estimated total algal carbon for each division. These means are weighted to give annual mean carbon densities as performed for cell densities. A comparison of Tables 2a and 2b shows that diatoms comprise the largest fraction of any division, being around half the annual phytoplankton measured either as cells or as estimated carbon. The next most abundant group is that of the green algae at about 20% for cell density or estimated carbon density. However, the remaining divisions make up very different fractions of the average total near-surface algae. Microflagellates and blue-greens are apparently over-represented when measured in cell density as compared with estimated carbon density. All other divisions make up much larger fractions of the total assemblage when measured in estimated carbon. In magnitude, the largest difference is perhaps of dinoflagellates, which jump from only 2% of the population as cells to 13% as estimated carbon. Microflagellates, on the other hand, show a nearly parallel drop from 16% as cells to only 5% as estimated carbon. The seasonal changes of the divisions will be discussed in greater detail.

Diatoms

During IFYGL, this group comprises just under half the phytoplankton as cells and just over half as estimated carbon on an annual basis (Tables 2a and 2b). It shows a single large bloom period during spring (March to June -- see Figs. 2 and 3) when densities are about eight times those of the other seasons. Diatoms are more abundant than any other algal type except during the August cruise, when, in terms of estimated carbon density, both greens and blue-greens are more abundant. In terms of cell density, diatoms are also at least equalled in the two succeeding cruises (in November) by blue-greens, and in the final June cruise, they are outnumbered by microflagellates. Thus, although clearly the most important division numerically, when a compensation is made for size, diatoms apparently constitute an even greater fraction of the lake's algae and dominate during IFYGL in all but the August cruise.

Tables 3a and 3b give the densities of the most abundant species. The dominant genus is seen to be *Stephanodiscus*. In terms of estimated carbon,

TABLE 2. Mean densities of phytoplankton types. See text for method of calculating grand average and percent. "w/o" means without heterocysts. "w/" means with heterocysts. (a) mean cell densities (cells/ml). (b) mean estimated carbon densities (μgC/l).

Table 2a

ALGAL TYPE	CRUISE # 1 May72	2 Jun72	3 Jul72	4 Aug72	5 Oct72	6 Nov72	7 Feb73	8 Mar73	9 Apr73	10 Jun73	GRAND AVE	PCNT
diatom	1397	1661	485	221	218	194	225	757	1460	857	559	46.6
green	490	947	318	775	141	48	26	47	40	135	264	22.0
flagellate	604	684	262	23	119	38	15	43	113	1532	191	15.9
blue-green w/o	121	83	36	86	366	184	91	43	23	151	127	10.6
dinoflagellate	101	22	40	30	29	9.5	9.8	21	31	38	29	2.4
blue-green w/	1.3	5.1	42	116	5.6	8.7	2.4	0	0	4.3	25	2.1
cryptomonad	8.8	22	0	0	0	.2	3.5	6.0	9.3	2.5	3.5	.29
chrysophyte	2.1	2.6	.1	.4	.2	0	.1	.3	.7	7.6	.7	.06
euglenoid	3.6	.1	0	0	0	0	0	0	0	.3	.2	.02
TOTAL	2728	3426	1182	1253	878	482	372	917	1677	2427	1199	

Table 2b

ALGAL TYPE	CRUISE # 1 May72	2 Jun72	3 Jul72	4 Aug72	5 Oct72	6 Nov72	7 Feb73	8 Mar73	9 Apr73	10 Jun73	GRAND AVE	PCNT
diatom	104.7	133.9	27.1	13.1	14.6	14.5	16.4	47.3	113.5	64.6	39.9	57.7
green	7.9	15.4	6.1	49.9	11.2	5.6	1.6	2.3	1.1	3.4	11.8	17.0
dinoflagellate	34.5	5.2	7.3	16.1	4.6	2.4	2.7	5.4	13.0	13.9	9.1	13.1
flagellate	11.6	12.9	4.8	.4	2.2	.9	.3	.9	3.1	28.7	3.7	5.3
blue-green w/o	1.2	3.8	3.3	1.1	4.3	1.9	1.2	.8	1.1	11.8	2.3	3.7
cryptomonad	3.1	8.5	.0	.0	.0	.06	1.3	2.2	3.6	1.0	1.3	1.9
blue-green w/	.04	.1	1.1	3.9	.4	.3	.1	.0	.0	.2	.8	1.2
chrysophyte	.5	.2	.1	.5	.1	.04	.03	.04	.2	.8	.2	.28
euglenoid	1.0	.03	.0	.0	.0	.0	.0	.0	.0	.07	.07	.10
TOTAL	164.5	180.0	49.8	82.1	36.3	25.6	23.8	59.0	135.6	124.3	69.2	

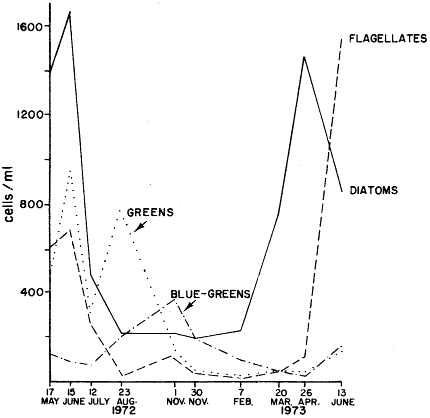

FIG. 2. Cell density for major algal types *vs.* cruise date.

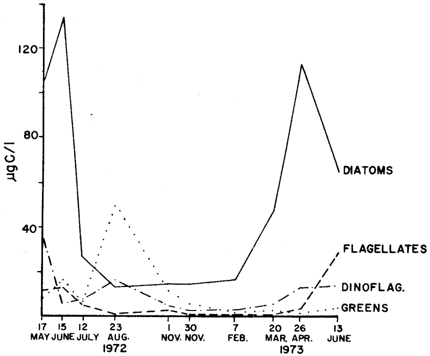

FIG. 3. Estimated carbon density for major algal types *vs.* cruise date.

TABLE 3. Mean densities of phytoplankton species. See text for method of calculating grand average and percent. (a) mean cell densities (cells/ml). (b) mean estimated carbon densities (μgC/l).

Table 3a

SPECIES OR GENUS	CRUISE # 1 May72	2 Jun72	3 Jul72	4 Aug72	5 Oct72	6 Nov72	7 Feb73	8 Mar73	9 Apr73	10 Jun73	GRAND AVE	PCNT
flagellate #1	581	669	262	22	119	30	14	40	70	1511	182	15.2
Stephanodiscus minutus	121	177	57	3.7	9.5	8.7	12	118	353	297	77	6.4
Stephanodiscus subtilis	172	265	186	62	39	16	3.6	126	14	39	74	6.1
Stephanodiscus binderanus	480	681	31	.7	7.5	13	6.0	4.6	44	80	74	6.1
Asterionalla formosa	131	184	24	5.0	20	35	36	101	312	103	72	6.0
Gomphosphaeria wichurae	5.7	3.9	.0	2.4	196	148	72	34	11	.0	62	5.2
Stephanodiscus hantzschii	186	38	32	2.3	17	35	54	166	110	24	60	5.0
Scenedesmus bicellularis	370	548	3.7	.7	11	8.7	15	28	25	31	59	4.9
Gloeocystis planctonica	35	106	233	133	23	.0	.0	.3	1.1	36	54	4.5
Stephanodiscus tenuis	38	15	10	.5	14	6.0	30	107	355	81	54	4.5
Fragilaria crotonensis	79	72	21	124	28	16	3.3	7.0	39	75	42	3.5
Oocystis spp.	2.0	3.5	2.2	116	26	6.7	1.9	.3	1.9	1.9	23	1.9

Table 3b

SPECIES OR GENUS	CRUISE # 1 May72	2 Jun72	3 Jul72	4 Aug72	5 Oct72	6 Nov72	7 Feb73	8 Mar73	9 Apr73	10 Jun73	GRAND AVE	PCNT
Stephanodiscus binderanus	48.7	69.2	3.1	.07	.8	1.3	.6	.5	4.4	8.1	7.5	10.8
Peridinium spp.	31.1	3.8	4.2	13.1	1.7	1.8	2.2	4.3	12.6	12.9	7.3	10.6
Stephanodiscus minutus	10.7	15.7	5.0	.3	.8	.8	1.1	10.5	31.3	26.3	6.9	9.9
Asterionella formosa	7.9	11.0	1.4	.3	1.2	2.1	2.2	6.1	18.7	6.2	4.3	6.2
Stephanodiscus tenuis	2.9	1.2	.8	.04	1.1	.5	2.3	8.2	27.4	6.3	4.2	6.0
flagellate #1	10.7	12.3	4.8	.4	2.2	.5	.3	.7	1.2	27.8	3.4	4.8
Melosira islandica	10.6	13.4	.4	.2	.3	.4	.9	2.5	11.5	1.5	2.8	4.0
Fragilaria crotonensis	5.2	4.7	1.4	8.2	1.8	1.1	.2	.5	2.6	4.9	2.8	3.9
Stephanodiscus subtilis	6.1	9.4	6.6	2.2	1.4	.6	.1	4.5	.5	1.4	2.6	3.8
Phacotus lenticularis	.0	.0	.2	12.2	.6	.7	.2	.2	.09	.0	2.1	3.1
Staurastrum paradoxum	.0	.0	.0	5.0	2.8	2.2	.3	.8	.05	.0	1.6	2.3
Oocystis spp.	.1	.2	.1	6.9	1.6	.4	.1	.02	.1	.1	1.4	2.0

the most abundant diatoms are probably *Stephanodiscus binderanus* and *S. minutus*, which together make up 20% of the estimated annual standing crop of algal carbon in the near surface water. In terms of carbon, other important diatoms are (Table 3b) *Asterionella formosa, Stephanodiscus tenuis, Melosira islandica, Fragilaria crotonensis*, and *S. subtilis*. In terms of cell density (Table 3a) the list is similar, but includes the small *Stephanodiscus hantzschii* and not *Melosira islandica*.

Stephanodiscus binderanus undergoes extreme density variations, dropping from its highest to its lowest values (i.e. by a factor of 1000) between June and August 1972. No other well distributed diatom undergoes such extreme and rapid variations. The August cruise is the one of lowest total diatom carbon density (Table 2b) and begins a period of low values for most diatom taxa. However, *Fragilaria crotonensis*, counters this trend, reaching its highest mean density during this month, when it constitutes over 60% of estimated diatom carbon and nearly 60% of total diatom cell density.

Green Algae

This group is the second most abundant, constituting about 20% either as estimated carbon or cell density (Tables 2a and 2b). Fig. 3 shows a single major peak of carbon density for this division in August 1972 when diatoms are at low densities. This peak is due to a general population increase of green algae, but especially to blooms of *Phacotus lenticularis, Oocystis* spp., *Staurastrum paradoxum* (Table 3b), and *Ulothrix subconstricta*, taxa which range from average to large size (Table 4). Figure 2 shows that this peak in carbon density is paralleled by a similar peak in cell density for the August cruise. Figure 2 also shows, however, another larger peak during June which has only a very minor parallel peak in carbon density (Fig. 3). This June peak is due to a bloom of *Scenedesmus bicellularis* and other small greens including *Ulothrix* sp. #1, *Ankistrodesmus falcatus* and *Coccomyxa coccoides*. These algae are quite small and contribute little to the total estimated algal carbon, despite their very large numbers. The green algae all seem to fit into one of two categories: those which show peak abundance during the June 1972 cruise and those which show peak abundance during the August 1972 cruise. Only one -- *Pediastrum duplex*, which has a sharp pulse for the early November cruise -- significantly deviates from this rule. Also, as a general rule, each species of greens shows a marked tendency for extreme population fluctuations.

Dinoflagellates

In terms of cell density, this division constitutes a relatively minor portion of the lake's algae (2.4% on an annual basis -- see Table 2a). However, in terms of estimated carbon, this division is very important (13.1% on an annual basis -- Table 2b). This is due almost exclusively to the genus *Peridinium*, which comprises about 81% of estimated annual dinoflagellate carbon (Tables 2b and 3b). *Peridinium* spp. apparently constitute over 10% of the lake's algal carbon (Table 3b), and is thus the second most abundant genus (behind *Stephanodiscus*) in terms of estimated carbon.

Dinoflagellates reach greatest abundance in the May and August cruises. During the August cruise, this division ranks second only to greens in terms of estimated carbon. Abundance declines through the fall and winter to

TABLE 4. Summary data of phytoplankton species and categories. Presented are division (B=blue-green without heterocyst, Bw=blue-green with heterocyst, G=green, D=diatom, Cr=cryptomonad, Ch=chrysophyte, Dn=dinoflagellate); estimated carbon content in pgC/cell; annual mean cell and carbon density (see text for calculation method).

species or category	division	pgC/ cell	annual mean cells/ml	annual mean μgC/l
Agmenellum thermalis	B	3.4	.43	.0015
Anagaena flos-aquae	Bw	27.	10.	.27
A. sp. #1	Bw	18.	.92	.017
A. variabilis	Bw	30.	13.	.39
Anacystis cyanea	B	8.1	16.	.13
A. incerta	B	2.3	17.	.039
A. thermalis	B	44.	3.8	.16
Ankistrodesmus falcatis	G	12.	13.	.16
A. setigerus	G	20.	.88	.017
Asterionella formosa	D	60.	72.	4.3
Borodinella sp. #1	G	21.	1.6	.034
Botrycoccus braunii	G	14.	10.	.14
Coccomyxa coccoides	G	1.2	3.1	.0035
Coelastrum microprorum	G	31.	14.	.45
Coscinodiscus subsalsa	D	350	.77	.27
Crucegenia quadrata	G	3.0	.38	.0011
C. rectangularis	G	4.6	.32	.0015
Cryptomonas erosa	Cr	380	3.4	1.3
Cyclotella meneghiniana	D	210	.24	.052
Diatoma tenue	D	42.	.97	.041
D. tenue var. *elongatum*	D	60.	19.	1.1
Dinobryon divergens	Ch	75.	.12	.0088
D. sociale	Ch	88.	.31	.028
Eudorina elegans	G	78.	4.3	.34
flagellate #1	F	18.	180	3.4
flagellate #2	F	42.	8.0	.34
Fragilaris capucina	D	55.	11.	.60
F. crotonensis	D	65.	42.	2.7
F. intermedia	D	60.	.62	.038
Glenodinium and *Gymnodinium* spp.	Dn	96.	13.	1.3
Gloeocystis planctonica	G	13.	54.	.71
G. sp. #1	G	44.	2.9	.13
Gomphosphaeria aponina	B	35.	3.1	.11
G. lacustris	B	3.8	8.4	.032
G. wichurae	B	7.7	62.	.48
Lagerheimia ciliata	G	38.	1.1	.041
Melosira granulata	D	85.	.57	.048
Ml islandica	D	120	23.	2.8
Nitzschia acicularis	D	27.	1.7	.045
N. bacata	D	98.	6.4	.62

TABLE 4 continued.

species or category	division	pgC/ cell	annual mean cells/ml	annual mean µgC/l
Nitzschia dissipata	D	25.	3.8	.094
N. filiformis	D	26.	.75	.020
N. holsatica	D	18.	1.5	.026
N. sp. #2	D	250	3.0	.75
Oocystis spp.	G	59.	23.	1.4
*Oscillatoria bornetii**	B	460	.57	.26
*O. limnetica**	B	71.	15.	1.1
Pediastrum duplex	G	34.	.61	.021
P. glanduliferum	G	34.	12.	.40
P. simplex	G	27.	4.0	.11
Peridinium spp.	Dn	470	15.	7.3
Phacotus lenticularis	G	200	11.	2.1
Scenedesmus bicellularis	G	13.	59.	.76
S. quadricauda	G	91.	.71	.065
S. quadricauda var. *longispina*	G	78.	2.6	.21
S. quadricauda var. *maximus*	G	250	.82	.20
S. quadricauda var. *quadrispina*	G	36.	4.6	.17
Sphaerocystis schroeteri	G	21.	1.1	.024
Staurastrum paradoxum	G	1200	1.3	1.6
Stephanodiscus alpinus	D	110	12.	1.3
S. binderanus	D	100	74.	7.5
S. hantzschii	D	21.	60.	1.3
S. minutus	D	89.	77.	6.9
S. niagarae	D	790	.49	.39
S. subsalsus	D	20.	.39	.0079
S. subtilis	D	35.	74.	2.6
S. tenuis	D	77.	54.	4.2
Surirella angusta	D	140	5.0	.69
Synedra ostenfeldii	D	38.	.85	.033
Tabellaria fenestrata	D	140	8.4	1.2
Tetraedron minimum	G	27.	.30	.0081
Ulothrix sp. #1	G	34.	7.8	.27
U. subconstrictum	G	53.	19.	1.0
TOTAL		57.7+	1199.	69.2

* first two columns of numbers give respectively: pgC/filament and annual mean filaments/ml

\+ mean carbon content per cell obtained by dividing annual mean carbon density by annual mean cell density

increase again in the spring of 1973. However in terms of either carbon or cell density, this division displays less seasonal variation than any other except diatoms.

Microflagellates

This is a composite category of individuals which are small and difficult to identify and mainly includes species of greens, haptophytes, and chrysophytes. This group is subdivided into categories of larger individuals (flagellate #2, 42 pg-C/cell) and smaller individuals (flagellate #1, 18 pg-C/cell). In terms of either cell or estimated carbon density, flagellate #1 is substantially more abundant than flagellate #2 (see Table 4).

This group constitutes 16% of the total annual mean cell density (Table 2a) and in spring samples is extremely abundant (Fig. 2). During the last cruise (June 1973), microflagellates outnumber all other groups combined. When measured as estimated carbon, however, microflagellates contribute only about 5% to the total estimated algal carbon (Table 2b) and take on a role of substantially lower importance in all cruises.

Blue-greens

Like microflagellates, this group is composed primarily of small individuals, and therefore takes on a greater relative importance when measured in terms of cell density than in estimated carbon density. It contributes about 13% to total annual average cell density but only about 5% to average carbon density (Tables 2a and 2b).

In terms of cell density, blue-green algae reach maximum abundance at the early November cruise. (Note that an unmeasured maximum could and probably does occur during the 2-month period between the late August and early November cruises. See Fig. 2.) This peak in early November is due mainly to a bloom of *Gomphosphaeria wichurae*, which composes 53% of total blue-greens for that cruise, and also to a bloom of *Anacystis cyanea*, which composes another 23%. However, both of these are small (8 pg-C/cell, Table 4) and together contribute only 47% of the blue-green carbon estimate for this cruise.

In terms of carbon, there is no strong peak at the early November cruise but rather a plateau between the July and early November cruises when mean estimated values range from 4.4 to 5.0 μg-C/l. This is due to biomass increase resulting from blooms of some heterocystaceous (nitrogen fixing) blue-greens during the July and August cruises, which are the only cruises such blue-greens are found in appreciable numbers. During the July cruise, a bloom of *Anabaena flos-aquae* contributes 25% to the total blue-green estimated carbon (and 54% of blue-green cell density); and, during the next cruise in August, the continuing bloom of *A. flos-aquae* is augmented by a bloom of *A. variabilis* which contributes 43% of the blue-green carbon (and 35% of the blue-green cells). On an annual basis, blue-greens with heterocysts (assumed nitrogen fixers) comprise 26% of total blue-green carbon or 16% of total blue-green cell density.

The cruise with the highest concentration of blue-greens in terms of estimated carbon is the last cruise, during June 1973. Estimated blue-green carbon density is 12 μg-C/l, which is more than twice that of the bloom of

July-November 1972. This high carbon concentration for blue-greens is almost entirely due to a bloom of *Oscillatoria* spp., which account for 98% of the 12 μg-C/l. Most of the contribution by *Oscillatoria* is due to one species, *O. limnetica*, which contributes 75% of total blue-green carbon for this cruise.

Oscillatoria limnetica is, in terms of estimated carbon, the most abundant blue-green on an annual basis (Table 4). To evaluate its importance in terms of cell density, it is necessary to first note the ambiguity involved in defining the functional unit of *Oscillatoria* (as well as several other genera, each of minor importance during IFYGL). It is a general practice to report densities of this genus in terms of numbers of filaments rather than in terms of number of cells which compose the filaments. This is because the cross-walls, which form to separate cells, close slowly. Thus, it is usual for a filament of *Oscillatoria* to contain long sections through which cytoplasm can freely pass. It is, however, not entirely unreasonable to define a partially closed cross-wall as separating two different cells. The functional unit would then be the partially formed cell, of which there are about 80 per visible section of filament. This factor of 80, when multiplied by the average annual filament count of 14.8/ml for *Oscillatoria limnetica* (Table 4), makes this the most abundant species in the lake at 1200 (partial) cells/ml. This equals the combined total of all other algal cells.

Cryptomonads

This division is essentially represented by only one positively identified taxon, *Cryptomonas erosa*, but certainly also contains members which are counted under the composite microflagellate category discussed above.

Cryptomonas erosa is a large species (Table 4) and thus, though found in small numbers, comprises 2% of total mean estimated carbon (Table 2b). It is apparently a spring species that reaches peak abundance during the June 1972 cruise. It disappears after this cruise and begins a comeback after December.

Chrysophytes

This is another division which contains large individuals. Though all species are fairly common, the most numerous is *Dinobryon sociale*. In terms of estimated carbon, *Mallamonas* spp. are the biggest contributers, especially *M. alpina*. This division also certainly has individuals included in the composite microflagellate category.

Euglenoids

This division is represented by *Phacus* spp. as well as some possible individuals counted as microflagellates. *Phacus* spp. is a very minor constituent of the phytoplankton of the lake.

Summary of Seasonal Phytoplankton Changes

Examination of Fig. 3 and Table 2b leads to the observation that, in terms of estimated carbon of major groups, the apparent annual phytoplankton cycle as evidenced during IFYGL can be broken up into three general time

periods. The first is from March through June, during which total algal content of the lake is maximum and when diatoms dominate the lake's algae. Cryptomonads, chrysophytes, euglenoids, and microflagellates also attain their highest abundances at this time. The second period starts in August and ends some time before November. During this time the green and blue-green algae reach their highest relative importance. The third period runs from December to February, and during this time total estimated algal carbon reaches its lowest values. Due to a decline of other types, diatoms regain their relative dominance. In terms of cell density, the pattern is very much the same (Fig. 2 and Table 2a) as for estimated carbon.

To examine the spatial distributions of phytoplankton during IFYGL, spatial data are presented for all cruises, and three of those cruises will be discussed in detail, taken one each from the three time periods discussed above. The three cruises are #2 (June 1972), #4 (August 1972), and #6 (late November 1972). The June cruise will be discussed in special detail to explain and illustrate the use of PCA in interpreting the data.

NEAR-SURFACE PHYTOPLANKTON SPATIAL PATTERNS

Carbon Density PCA for Cruise 2 (12-16 June 1972)

Station ordination is shown in Fig. 10a.* Numbers refer to station numbers (see Fig. 12a). Station numbers in Fig. 10a are located relative to the scores on the first and second principal components. Taxa ordination is shown in Fig. 10b. Abbreviations are given in Table 1. The first and second principal components are represented on the X- and Y-axes respectively. Taxa abbreviations on Fig. 10b are located relative to loadings on the first two principal components. The cross in the figures shows the origin. Vertical lines in Figs. 10a and 10b represent the value associated with the third principal component. A line upward from a name represents a positive value and a line downward represents a negative one. These lines are foreshortened by a factor of about five to give perspective to what is intended to be a representation of three dimensions. In interpretation, greatest importance is given to the first two principal components. Summary statistics are shown in Table 5.

Peripheral regions in Fig. 10a were chosen to be those labeled A, B, C, and D. Regions A, C, and D are separated on the basis of principal components 1 and 2. Region B is separated from region C on the basis of the third principal component, which is negative in C and positive in B. Region D grades into region C through region c. The decision where to draw boundaries and how many regions to define is somewhat arbitrary, but, as will be seen, basic conclusions will not be affected by these decisions.

Figure 10a may be compared with Fig. 10b to interpret the results. Taxa with positive loadings on the first principal component (PC1) are found to the right of the origin. Taxa with positive loadings on the second principal component (PC2) are found above the origin. Thus taxa with positive loadings on both PC1 and PC2 are found in the upper right corner of Fig. 10b. These would include *Melosira islandica, Stephanodiscus binderanus, Nitzschia bacata,* and *Scenedesmus bicellularis*. As an example, *Melosira islandica* has a lake-wide average carbon density for cruise 2 of 13.4 μgC/l (corresponding to an average cell density of 112 cells/ml). Since this taxon has a positive loading on PC1 (it is located to the right of the origin), it will add a positive contribution to the score on PC1 for any station at which the density of this taxon is greater than 13.4 μgC/l. Conversely, if a station has a density for *Melosira islandica* less than 13.4 μgC/l, the contribution to its score by this taxon will be negative. Thus stations on the right side of Fig. 10a will tend to have a density of *Melosira islandica* greater than 13.4 μgC/l. Stations on the left side of Fig. 10a will tend to have relatively (i.e. with respect to the mean of 13.4 μgC/l) low densities of this taxon.

This taxon also has a high positive loading on the second principal component and is thus located near the top of Fig. 10b. Using the same arguments just given, it would be expected that stations located near the top of Fig. 10b have relatively high densities and those near the bottom relatively low densities of *Melosira islandica*.

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*All tables (7 and above) and figures (8 and above) referenced from this point are located at the end of this section to facilitate comparison of data.

TABLE 5. Summary statistics. Percent variance removed in PCA's, number of taxa used in PCA's, cruise dates.

PERCENT VARIANCE REMOVED BY PCA ON ESTIMATED CARBON DENSITY

	CRUISE NUMBER 1	2	3	4	5	6	7	8	9	10
PC1	23.6	22.4	26.4	25.3	31.6	24.4	51.5	29.7	34.9	19.7
PC1,2	41.6	35.6	46.0	43.3	50.4	41.7	69.4	47.3	48.5	36.3
PC1-3	54.1	47.6	58.2	54.1	64.2	54.2	81.2	61.7	58.5	49.1

PERCENT VARIANCE REMOVED BY PCA ON % ESTIMATED CARBON DENSITY

	CRUISE NUMBER 1	2	3	4	5	6	7	8	9	10
PC1	48.2	63.4	27.4	41.3	39.8	52.0	36.9	41.7	45.1	43.7
PC1,2	84.6	77.7	45.3	68.6	57.8	65.3	61.8	65.1	73.1	64.4
PC1-3	90.1	86.1	58.4	85.4	71.9	75.1	75.7	77.5	83.2	77.3

NUMBER OF SAMPLES AND TAXA IN EACH PCA

	CRUISE NUMBER 1	2	3	4	5	6	7	8	9	10
no. of samples	33	58	60	59	59	54	37	33	46	48
no. of taxa	21	20	14	12	11	11	11	16	19	19

CRUISE DATES

CRUISE #	DATE
1	15-19 May 1972
2	12-16 June 1972
3	10-14 July 1972
4	21-24 August 1972
5	30 October - 3 November 1972
6	27 November - 1 December 1972
7	5-9 February 1973
8	19-22 March 1973
9	24-28 April 1973
10	11-14 June 1973

Combining all these observations leads to the following general conclusion: If a taxon is located in one corner of Fig. 10b, it will tend to be found in highest density at stations in the corresponding corner of Fig. 10a, and it will be found in lowest densities in the opposite corner of Fig. 10a. Unfortunately, conclusions drawn about algal distribution using these generalizations are not always correct. They must be checked against the data for verification. Much of the remainder of this section will deal with this verification.

Since *Melosira islandica* is located near the top of Fig. 10a, it might be expected that its density is highest in region (cluster) A in Fig. 10a. The stations at which the near-surface density of this taxon is greatest for cruise 2 are shown in Table 6. Note that of the five stations of highest density, four (numbers 20, 54, 1, and 7) are in region A as expected. The fifth station (number 17) is not in this group, but is rather in region B. All of these stations are near the top right corner of Fig. 10a as expected.

Since *Melosira islandica* is in the upper right (i.e. has positive loadings on PC1 and PC2) of Fig. 10b, stations of low density might be expected to be found in the lower left (negative scores for PC1 and PC2) of Fig. 10a. The stations to the lower left of the origin belong to regions D and C. The stations of lowest density are shown in Table 6 and all of these belong to regions D and C as expected.

A taxon close to *Melosira islandica* on Fig. 10b is *Stephanodiscus binderanus*. For this reason it would be expected that *Stephanodiscus binderanus* has a similar distribution to that of *Melosira islandica* -- that is, high density in region A and low density in regions D and C. Table 6 shows that the five stations of highest density are in region A except for station 92, which is in region a. The five stations of lowest density are all in region D except for station 32 which is in region a. The trends for *Stephanodiscus binderanus* are, then, similar to those of *Melosira islandica* but are perhaps slightly weaker with respect to patterns of Fig. 10a. As a general rule, taxa furthest from the origin in a taxon ordination plot (such as that shown in Fig. 10b) will display strongest patterns relative to its associated station ordination plot (such as in Fig. 10a).

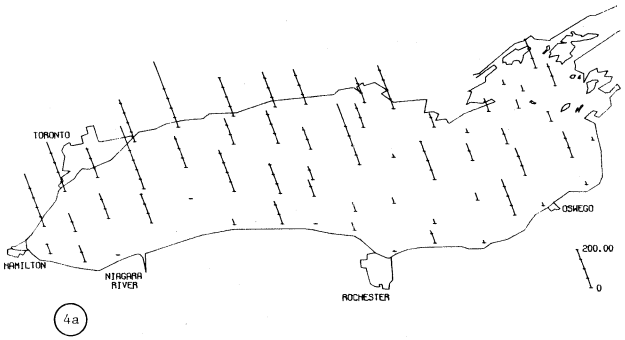
Figures 4a and 4b show areal distributions of these two species. Their patterns of distribution are similar, as expected from the PCA. Both show a tendency for highest densities in the northwestern part of the lake. Both also show high values in the eastern section and lowest values in the southern side from the Niagara River to Rochester. Correspondence is not perfect, but in terms of general patterns, their distributions are similar.

A taxon whose distribution would be expected to be different is *Stephanodiscus subtilis*, which is located near the bottom of Fig. 10b. Since region C is in the corresponding position in Fig. 10a, it would be expected that *Stephanodiscus subtilis* would be most abundant in that region. Since it has a positive loading on PC1 and a negative loading on PC2, it would be expected that its lowest densities would be found at stations with negative scores for PC1 and positive scores for PC2. Therefore lowest densities should be in regions D and a.

Table 6 shows the five stations of highest density and the five of lowest. The stations of highest density are all in region C, as expected,

TABLE 6. Highest, lowest, and mean densities for selected taxa from cruise #2.

Melosira islandica			*Stephanodiscus binderanus*			*Stephanodiscus subtilis*		
STA #	μgC/l	cells/ml	STA #	μgC/l	cells/ml	STA #	μgC/l	cells/ml
stations of highest density								
20	41	341	92	322	3169	69	54	1512
17	40	329	7	276	2723	77	41	1152
54	38	318	19	272	2677	79	38	1070
1	33	277	35	255	2509	78	35	980
7	31	260	8	252	2486	24	20	563
stations of lowest density								
12	0	0	26	0	0	56	.6	17
26	0	0	32	0	0	71	1.3	36
42	0	0	40	0	0	40	1.3	36
60	.5	4	45	0	0	32	1.5	42
73	1.5	13	62	0	0	12	1.6	46
lakewide averages								
	13.4	112		69.2	681		9.4	264



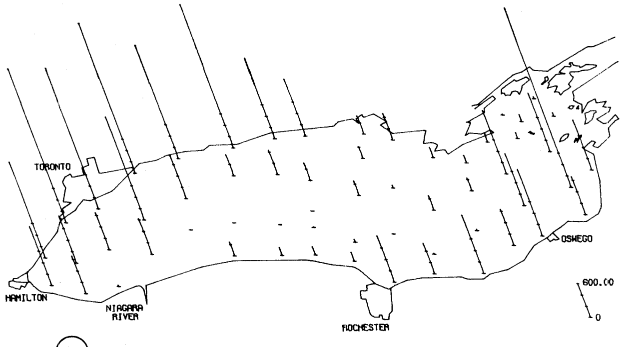


FIG. 4. Distributions of two western dominant diatoms of cruise #2.
(a) *Melosira islandica* (cells/ml) (b) *Stephanodiscus binderanus* (cells/ml)

except for station 24, which is in region B. The stations of lowest density are all in region D except for station 32, which is in region a.

The distribution of *Stephanodiscus subtilis* is shown in Fig. 5a. Its highest abundance is near Pt. Petre in the northeastern part of the lake. On the basis of Fig. 10b it would be expected that *Stephanodiscus minutus* and *Stephanodiscus subtilis* would have similar distributions since they are placed close to one another on this figure. The distribution maps in Figs. 5a and 5b verify that these two taxa do have very similar distribution patterns.

As noted above, Fig. 10b suggests that *Stephanodiscus subtilis* has a distribution very different from *Melosira islandica* or *Stephanodiscus binderanus*. This is verified by comparing Figs. 5a and 5b with 4a and 4b. *Stephanodiscus subtilis* (Fig. 5a) shows peak values where *Melosira islandica* and especially *Stephanodiscus binderanus* (Fig. 4b) show low values.

The geographic locations of the stations in the clusters of Fig. 10a are shown in Fig. 12a. An important feature of this map is that clusters from Fig. 10a form essentially contiguous regions in the lake. This greatly simplifies interpretation. Region A has, as discussed above, high densities of *Stephanodiscus binderanus* and *Melosira islandica*. It is located along the northwestern shoreline. Region a, which on the basis of Fig. 10a is expected to be related to region A but with somewhat lower densities of these taxa, is adjacent to region A on the west side of the lake. This region, however, also has several of its stations near the eastern shore. There is a very high correspondence between the locations of these regions and the locations of areas of high density for *Stephanodiscus binderanus* and *Melosira islandica* in Figs. 4a and 4b, as is expected on the basis of the earlier discussion.

Region C is made up of a contiguous group of stations in Fig. 12a near Pt. Petre in the northeastern part of the lake. Stations of region c, which has a similar phytoplankton composition to (but lower densities than) region C, are located in the eastern part of the lake. Taxa belonging to this region were seen to be *Stephanodiscus subtilis* and *Stephanodiscus minutus*. The maps of Figs. 5a and 5b may be compared with Fig. 12a to show the similarity.

Looking back at Fig. 10b, an important general observation can be made: Almost all taxa have positive loadings on PC1, as evidenced by their location to the right of the origin. The interpretation of this pattern is that most taxa tend to show relatively high density at the same stations. That is, most taxa are positively correlated with one another. As a result of this pattern, it is expected that, as a general rule, stations on the left side of Fig. 10a should have low total algal density and stations on the right should have relatively higher total density. The region farthest to the left in Fig. 10a is region D. As discussed above, *Melosira islandica, Stephanodiscus binderanus, S. subtilis, and S. minutus* all have lowest densities in this region. Figure 12a shows that region D is located in the mid-southern part of the lake. Figs. 6a and 6b show algal density both in terms of total estimated algal carbon density and in terms of cell density. It is seen by comparison of the two figures that region D is, as expected, located in a region of low density.

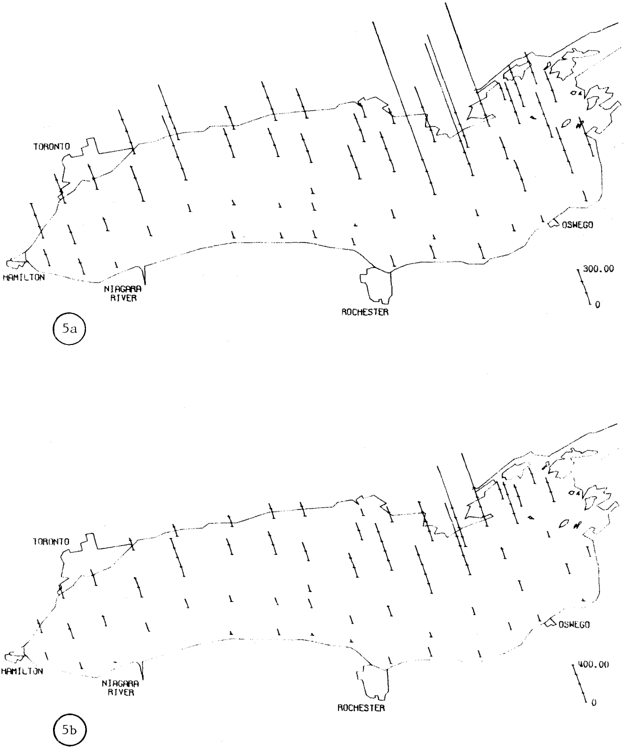
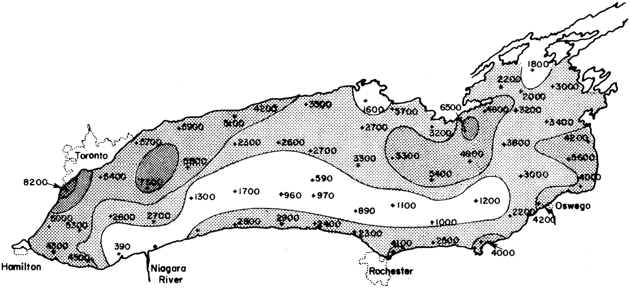
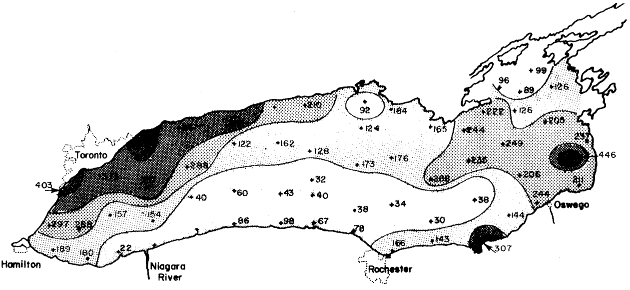


FIG. 5. Distribution of two eastern dominant diatoms of cruise #2.
(a) *Stephanodiscus subtilis* (cells/ml) (b) *Stephanodiscus minutus* (cells/ml)



6a



6b

FIG. 6. Distribution of total algal biomass for cruise #2. (a) total estimated cell density (cells/ml) (b) total estimated carbon density ($\mu gC/l$)

Nitzschia dissipata is the only taxon of Fig. 10b which has a significantly negative loading on PC1. This suggests that this taxon has a distribution pattern which is in some way opposite to the general pattern of the other taxa. This difference is best seen at station 12. This station has both the lowest estimated total carbon density (23 μgC/l) and the lowest total cell density (392 cells/ml) and is also the leftmost station on Fig. 10a. For many taxa, then, (e.g. *Melosira islandica* -- Table 6) density at this station is the lowest or one of the lowest. *Nitzschia dissipata*, however, reaches its second highest density at this station, and primarily for this reason the PCA has singled it out as being quite different from the others.

It is plainly not possible to discuss all other taxa and cruises in this much detail. To aid interpretation, a table of statistics for each taxon and region has been prepared. Table 10 shows mean carbon densities for all taxa of Table 1, whether used in the PCA or not. Also shown are F-statistics (based on an ANOVA assuming unequal sample size -- see Sokal and Rohlf 1969, p. 208) to indicate whether differences between means are significant.

For example, *Melosira islandica* (Table 10) has highest mean density in regions A and B (25 and 24 μgC/l) and lowest in region D (5 μgC/l) as is expected on the basis of the earlier discussion. Since Table 10 shows that the difference between means is significant for *Melosira islandica* (F-stat (p<.01,df=5,12) = 8.150) it is reasonable to conclude that, on the basis of the ANOVA, this taxon is most abundant in regions A and B and least in region D. To test the significance between any pair of means, a T-test using the standard errors of the means can be used. However, multiple comparisions may not be made this way. To obtain standard errors, divide the standard deviation given in Table 10 by the square root of the number of samples.

Table 10 also shows that *Melosira islandica* is the third most abundant taxon with respect to estimated carbon (lakewide average of 13.4 μgC/l) and reached a maximum density of 41.1 μgC/l.

The last entry in Table 10 is for total estimated algal carbon. It shows that the lakewide average estimated total carbon density is 180 μgC/l for this cruise. Region A has the highest average (318 μgC/l) and region D the lowest (50 μgC/l).

It is important to note that all carbon densities are estimates and may be in error by 50% or more. However, results of this PCA are identical with the results of the PCA based on cell density since estimated carbon for a taxon is a constant factor times cell density. That is, the grouping of the stations and taxa (Fig. 10a and 10b) will be the same. However, the ranking of the taxa will be different. For example, the eight most abundant taxa with respect to cell density (Table 7a) rank differently when ordered by average estimated carbon density (Table 7b). In both lists, *Stephanodiscus binderanus* is the most abundant. In terms of cell density flagellate #1 and *Scenedesmus bicellularis* are very nearly as abundant, but in terms of estimated carbon, flagellate #1 is 1/5 as abundant and *Scenedesmus bicellularis* 1/10 as abundant. In terms of cell density it would appear that diversity is rather high and diatoms share the lake equally with other types. But in terms of estimated carbon, *Stephanodiscus binderanus* is easily the most abundant taxon while diatoms appear to dominate the lake flora. In terms of cells/ml, diatoms constitute 48.5% (Stoermer et al. 1974) of the lake algae,

TABLE 7. Ranking of the eight most abundant taxa for cruise #2.
(a) in terms of cell density
(b) in terms of estimated carbon density

Table 7a

Rank	Taxon	Average cells/ml
1	*Stephanodiscus binderanus*	681
2	flagellate #1	669
3	*Scenedesmus bicellularis*	548
4	*Stephanodiscus subtilis*	264
5	*Asterionella formosa*	184
6	*Stephanodiscus minutus*	177
7	*Melosira islandica*	112
8	*Ankistrodesmus falcatus*	96

Table 7b

Rank	Taxon	Average μg-C/l
1	*Stephanodiscus binderanus*	69
2	*Stephanodiscus minutus*	16
3	*Melosira islandica*	13
4	flagellate #1	12
5	*Asterionella formosa*	11
6	*Stephanodiscus subtilis*	9
7	*Crytomonas erosa*	8
8	*Scenedesmus bicellularis*	7

but in terms of estimated carbon diatoms constitute 74.4% of the algae. Thus the ratio of diatoms to other algae is nearly 1 to 1 in terms of cell density but jumps to almost 3 to 1 when measured as estimated carbon.

PCA on % Carbon Density for Cruise 2

To more fully investigate the relationship of the algae in terms of carbon density, a second PCA is performed on the same taxa. In this PCA, the data used are in terms of percent carbon. For taxon i,

$$P_i = C_i/T * 100\%,$$

where C_i is the estimated carbon density of species i, T is the total estimated algal carbon density, and P_i the percentage carbon for species i. As in the previous analysis, stations are cases and taxa are variables. Unlike the previous analysis, however, the data are unstandardized (that is, the variance-covariance matrix is used). A summary of this PCA is given in Table 5. As seen in this table, a higher percentage of the variance is removed in this second analysis. PCA performed using the variance-covariance matrix will normally extract a greater percentage of the variance than a similar one using the correlation matrix. This is because there are fewer variables (taxa) contributing substantially to the total variance. That is, species low in abundance contribute less to total variance than the most abundant species. Contrast this with the previous analysis in which all species contributed equally due to the standardization.

The station ordination (based on principal component scores) is shown in Fig. 11a and the corresponding taxa ordination (based on loadings) is shown in Fig. 11b. There are three peripheral regions in Fig. 11a labeled A, B, and C and these respectively correspond in position with three taxa in Fig. 11b: *Stephanodiscus binderanus*, flagellate #1, and *Melosira islandica*. Thus it is expected that *Stephanodiscus binderanus* is most abundant (in terms of estimated percent carbon) in region A, flagellate #1 most abundant in region B, and *Melosira islandica* in region C. These expectations are borne out by Table 11, in which mean values for each taxon in each region are given. Only one taxon, *Stephanodiscus binderanus*, has its greatest abundance in region A, where it averages 63% of the total estimated algal carbon. Its second highest mean is in region a, and its least is in region C. Since *Stephanodiscus binderanus* is on the far left of Fig. 11b, this ordering is consistent with the locations of regions A, a, and C in Fig. 11a: A is farthest to the left, a is next to it and region C is furthest away. The geographic location of region A as shown in Fig. 12b is along the northwest shore of the lake and corresponds closely with the location of region A of the previous analysis as shown in Fig. 12a.

Table 11 shows that several taxa reach highest percent estimated carbon in region B. Flagellate #1 attains an average of 26% in region B and much lower averages in other regions. It is located at the top of Fig. 11b, in a position corresponding with region B of Fig. 11a. The other taxa which reach highest abundance in region B, however, are not located near the top of Fig. 11b. These taxa are *Nitzschia dissipata, N. acicularis, Gloeocystis planctonica, Glenodinium* spp., and *Gymnodinium* spp. The reason these are not located near the top of Fig. 11b (i.e. the reason PC2 does not load heavily on these taxa) is that the values of percent estimated carbon for these taxa are very small. For example, *Nitzschia acicularis* has, in region B, a mean of 0.6%, which is small in comparison with the 26% mean for flagellate #1 in the same region. This illustrates one important difference between this PCA and the previous one: in this PCA using the variance-covariance matrix, the scale is important

whereas in the previous one, using the correlation matrix, scale is removed by the standardization process. Thus, this PCA considers not only similarity in distribution of taxa, but also the magnitude of the values for those taxa.

The location of region B in Fig. 12b suggests that this region corresponds somewhat with areas of low total algal density (see Figs. 6a and 6b). This is because, for this cruise, *Nitzschia dissipata, N. acicularis, Glenodinium* spp., *Gymnodinium* spp., and especially flagellate #1 make up a greater proportion of the algal carbon when total algal carbon density is low.

On the basis of Figs. 11b and 11a it is expected that *Melosira islandica* and perhaps *Scenedesmus bicellularis* and *Asterionella formosa* have highest percent estimated carbon values in region C. Table 11 shows that each of these taxa attain highest densities in this region. *Melosira islandica* is located nearest the bottom of Fig. 11b because its average estimated carbon in this region is much higher than those for the other taxa in this region.

Another region seen in Fig. 11a is region D, which is located near the intersection of PC1 and PC2 and is distinguished from the other regions on the basis of PC3. Region D is the only one whose stations have PC3 values which are predominantly positive. Figure 11b suggests that this region is dominated in terms of estimated percent carbon by *Stephanodiscus minutus* and *S. subtilis*. This is verified by Table 11. No other taxa are most abundant in region D, although several (Table 11) are relatively abundant in region d, which is located in the ordination (Fig. 11a) between regions D and C. By comparing Fig. 12b with Fig. 12a, it is seen that region D of Fig. 12b (which is characterized in terms of percent carbon by *Stephanodiscus minutus* and *S. subtilis*) corresponds closely with region C of Fig. 12a (which is characterized in terms of carbon density by the same taxa).

Carbon Density PCA for Cruise 4 (21-24 August 1972)

Figure 16a shows the ordination of stations for the August cruise resulting from the PCA based on the correlation matrix of carbon density. Figure 16b shows the corresponding taxa ordination. Five regions are identified in Fig. 16a. Region C is represented by only one station, #60, which is separated from its nearest neighbor, region B, by large differences in each of the first three principal components. Regions E and D are close on the basis of the first two principal components but separated on the basis of the third.

Comparison of Figs. 16a and 16b suggests that region A contains stations with relatively high densities of *Peridinium* spp., *Lagerheimia ciliata*, *Oocystis* spp., and *Scenedesmus quadricauda* var. *quadrispina*. This is supported by Table 14, which gives average values for each taxon in each region. Figure 18a shows that the geographic locations of stations in region A are generally in the northeastern part of the lake.

Region B is related to region A, as is expected on the basis of Fig. 16a. Region B has relatively high densities of the four taxa characterizing region A (Table 14). Region B also has high densities of *Ankistrodesmus falcatus* and *Ulothrix subconstricta*. Other taxa abundant in this region are *Stephanodiscus subtilis* and *Ankistrodesmus setigerus*. Densities of these two taxa are not, however, significantly different in the identified regions (Table 14). Stations belonging to region B lie in the eastern part of the lake at the periphery of region A.

Region C is represented by one station, #60, which has the highest total carbon and total cell density of all stations for this cruise. It is characterized by very high densities of *Ulothrix subconstricta*, *Ankistrodesmus falcatus*, *Stephanodiscus subtilis*, and flagellate #1 (Table 14), as is expected. Although not indicated by Fig. 16b, the density of *Phacotus lenticularis* is also high here. However, this region has lower densities than region B of the taxa listed above which characterize region A.

Station #60 is located (Fig. 18a) near Rochester. It is of interest to note that the station nearest #60 in the ordination of Fig. 16a is station #72, which geographically is the nearest station to the east of #60 and is, like #60, an inshore station. The nearest inshore station to the west is #59, which has, on the basis of the Fig. 16a ordination, a very different community from that of station #60 or #72. It is reasonable to assume that the high densities of algae at station #60 are due to its proximity to Rochester. It is further reasonable to conclude that Rochester's effect on the lake extends primarily eastward during this cruise since stations to the east are more closely related to station #60 than those to the west.

Region D (upper left of Fig. 16a) is characterized by high densities of *Phacotus lenticularis* and, to a lesser extent, by *Staurastrum paradoxum* (Table 14). It is closely related to region E which is characterized by very low algal densities (Table 14). The difference is primarily due to the high densities of the above named taxa, which are among the four most important phytoplankton in terms of estimated carbon density. Region D (the region of low total density) is composed of stations which are, for the most part, located in the northeast quadrant of the lake. Its relative, region E, is located near it and generally to its south (Fig. 18a).

In summary, the general patterns for this cruise are high densities in the eastern and low in the western part of the lake. The western part is subdivided into northern and southern parts, with *Phacotus lenticularis* and *Staurastrum paradoxum* reaching high densities in the southern part. The eastern half of the lake likewise has a general north-south gradient. The northern part is characterized by, among others, *Peridinium* spp. The southern part appears to be influenced by Rochester and may be characterized by *Ulothrix subconstricta* and *Ankistrodesmus falcatus*. The lake at this time is dominated by the green algae. The most abundant taxa, in terms of lakewide average estimated carbon density, are *Peridinium* spp. (dinoflagellates) and *Phacotus lenticularis* (a green alga), which constitute about 15% of the estimated carbon. These are followed by three greens -- *Oocystis* spp., *Staurastrum paradoxum, Ulothrix subconstricta*--which constitute about 7% of the estimated carbon (see Table 14).

PCA on % Carbon Density for Cruise 4

Figs. 17a and 17b show the ordination of stations resulting from the PCA based on the variance-covariance matrix of percent estimated carbon density. Fig. 17a has four peripheral regions -- A, B, C , and D -- which correspond very closely in position with four taxa in Fig. 17b -- *Peridinium* spp., *Phacotus lenticularis, Staurastrum paradoxum,* and *Ulothrix subconstricta* (and its neighbor, *Stephanodiscus subtilis*).

On the basis of these figures, it is expected that region A has high relative densities of *Peridinium* spp. This is borne out in Table 15, which shows the genus to compose an average 52% of estimated carbon in region A. Geographically, region A is composed of three near-shore stations east of Toronto and one near-shore station west of Rochester. *Peridinium* spp. is also an important taxon in the PCA based on standardized estimated carbon density discussed above, but the geographic location of the region characterized by high absolute densities of *Peridinium* spp. is different from the location of the region characterized by high relative densities of *Peridinium* spp. (compare region A of Fig. 18a and region A of Fig. 18b).

Region B is characterized by high relative densities of *Phacotus lenticularis*, which composes an average of 41% of estimated carbon in this region. Region B is located (Fig. 18b) very near region A in the middle western half of the lake. Region C, characterized by *Staurastrum paradoxum* (which averages 26% of estimated carbon in this region), is located just south of region B along the southwestern shore. Its location and the location of region B correspond closely with the regions characterized by *Phacotus lenticularis* and *Staurastrum paradoxum* in the previously discussed PCA based on standardized estimated carbon (compare regions B and C of Fig. 18b with region D of Fig. 18a).

Region D (Figs. 17a and 18b) is characterized by high relative densities of *Ulothrix subconstricta* (average of 14% in this region). It is located just east of Rochester on the southern shore.

The regions AB, AD, and BD contain stations with percentages which are intermediate between the peripheral regions. (For example, region AB contains stations with a mixture of *Peridinium* spp. and *Phacotus lenticularis,* taxa characteristic of regions A and B respectively.) The intermediate regions AB, AD, and BD, however have in common a rather high percentage of *Oocystis* spp. (see Table 15). The pattern of community distribution based on relative abundance may be summarized as being one in which floristically distinct regions coexist in the western half of the lake, while what appear to be mixtures of *Oocystis* spp. and taxa from these regions occur in the eastern half.

Carbon Density PCA for Cruise 6 (27 Nov. - 1 Dec. 1972)

Algal population densities during this cruise are very low and patterns determined by PCA are weaker than those for either the June or August cruises. The ordination of stations and taxa resulting from the PCA based on the correlation matrix of estimated carbon density are shown in Figs. 22a and 22b. Regions A and a are characterized by relatively high densities of *Stephanodiscus subtilis, S. hantzschii,* flagellate #1, *Glenodinium* spp., and *Gymnodinium* spp., but patterns are not strong. Densities in region A are in general higher than in region a for these taxa (Table 18). Regions A and a consist of four stations in the northeast corner of the lake and one station (#2) in the far southwestern corner (Fig. 24a). As can be seen in Fig. 22a, the placement of station #2 with region a is somewhat arbitrary. Its association with the stations in this region results primarily from its extremely high (for this cruise) density of *Phacotus lenticularis*.

Region D (Fig. 22a) contains stations of relatively high density of *Stephanodiscus alpinus,* flagellate #2, and *Peridinium* spp. Stations belonging to this region are located generally in the northwestern part of the lake.

Regions B and C are similar to one another (Fig. 22a) and both have very low algal populations. Regions A and B are similar (Fig. 22a) and most stations belonging to region B are geographically located near region A stations in the eastern part of the lake (Fig. 24a). Regions C and D are similar (Fig. 22a) and stations belonging to region C are geographically located near those of region D in the western half of the lake. No specific differences between regions B and C can be determined from Table 18, however.

In summary, the lake during this cruise basically appears to have two different communities: *Stephanodiscus subtilis, S. hantzschii,* flagellate #1, *Glenodinium* spp., and *Gymnodinium* spp. in the northeastern corner of the lake and *Stephanodiscus alpinus*, flagellate #2, and *Peridinium* spp. in the north-western side. These two communities grade into one another through the central parts of the lake. Note that the two taxa with highest carbon densities *Staurastrum paradoxum* and *Asterionella formosa,* are not used in the PCA because the small number of individuals representing these taxa do not provide sufficient accuracy. Neither of these taxa belong to either community, but this may be due to their low accuracies.

PCA on % Carbon Density for Cruise 6

The PCA performed on the variance-covariance matrix of percent estimated carbon density results in the ordinations given in Figs. 23a and 23b. As is evident in Fig. 23b, clustering is quite poor. (This is primarily due to the exclusion of the two taxa with highest carbon densities, *Staurastrum paradoxum* and *Asterionella formosa*, because of their low cell counts.) Most of the grouping in Fig. 23a is based on the first principal component.

Region A (Fig. 23a) consists of stations with high percentage of *Peridinium* spp. (21% in this region -- see Table 19), and region a has high but somewhat lower values for this genus. These regions are located in the western part of the lake (Fig. 24b). Region B has high percentages of *Glenodinium* spp. and *Gymnodinium* spp. and a tendancy for high percentages of *Phacotus lenticularis*. This region and region b, which is similar to it, is composed of stations which are for the most part in the south-central section of the lake. Region C consists of stations at which none of the taxa used in the PCA occurs in such large percentages as to largely exclude others, as is somewhat the case in regions A and B.

Results of PCA for all Cruises and Summary of Patterns

For each cruise, the following are presented:

Ordination plot of stations based on scores from PCA based on correlation matrix of estimated carbon density (equivalent to a PCA on cell density) and its associated ordination plot of taxa,

map showing locations of regions determined from PCA,

table giving for each taxon and for the total of all algae: the estimated carbon density's grand mean and maximum, the mean and standard deviation for each region, F-stat based on an ANOVA assuming unequal sample sizes (Sokal and Rohlf, 1969, p. 208) and calculated degrees of freedom. The ANOVA tests the null hypothesis that the means of all regions are equal.

Ordination plot of stations based on scores from PCA based on variance-covariance matrix of estimated percent carbon density and its associated ordination plot of taxa,

map showing locations of regions determined from PCA,

table giving for each taxon and for the total of all algae: the grand mean percent estimated carbon density and maximum, the mean and standard deviation for each region, F-stat based on an ANOVA assuming unequal sample sizes (Sokal and Rohlf, 1969, p. 208) and calculated degrees of freedom. The ANOVA tests the null hypothesis that the means of all regions are equal.

Listing of the six taxa most abundant with respect to estimated carbon density, expressed as a percent which is calculated as (mean density for taxon)/(mean total density)*100%,

listing of the six taxa most abundant with respect to percent estimated carbon density, expressed as mean percentage of all stations.

Summary of patterns from PCA based on correlation matrix of estimated carbon density (equivalent to PCA on correlation matrix of cell density). Generally, only taxa which, between regions, show differences which are statistically significant are discussed. These taxa are not necessarily the most abundant ones. Taxa said to characterize a region may not be the taxa most abundant at that station. The term "high," when used in connection with a taxon's density, means high with respect to that taxon's average.

Summary patterns from PCA based on variance-covariance matrix of percent estimated carbon density. Generally, only taxa which, between regions, show differences which are statistically significant are discussed. These taxa are, with few exceptions, the most abundant in terms of percent estimated carbon.

In general, capital letters refer to regions with more exaggerated characteristics than regions referred to by small letters.

Explaination of Tables 8-27:

These tables provide descriptive statistical information about taxa relative to principal component analyses. On them are given:

- the *cruise date* (upper left corner)
- the *grand mean* and *maximum value* for each taxon. E.g. *Ankistrodesmus falcatus* has a grand mean estimated carbon density of 0.458 μgC/1 and a maximum of 3.755 μgC/1 for cruise #1 (see Table 8).
- the *region lables* and *number of stations* in each. E.g. region A has three stations according to Table 8.
- the *mean value* and *standard deviation* for each taxon in each region. E.g. Table 8 shows that in region A (as defined by Fig. 9a) *Ankistrodesmus falcatus* has an estimated mean carbon density of 0.535 μgC/1. Table 9 shows that in region C (of Fig. 9b) *Ankistrodesmus falcatus* has a mean percentage (defined as the sum of the percentages divided by the number of stations) of 0.207 and a standard deviation of 0.158.
- the *F-statistic, degrees of freedom,* and *significance* for each taxon. The F-statistic is based on an ANOVA testing the hypothesis that the region means are equal. The ANOVA assumes unequal sample sizes (Sokal and Rohlf, 1969, p. 208). A single asterisk indicates significance at the 5% level, and a double asterisk indicates significance at the 1% level. In Table 8, *Ankistrodesmus falcatus* shows an F-statistic of 19.779 with estimated degrees of freedom of 4 (numerator) and 8.5 (denominator). The double asterisk indicates that the hypothesis of equal means is rejected at the 1% level.

CRUISE 1 15-19 MAY 1972

Most abundant taxa on the basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
Stephanodiscus binderanus	30 %	*Stephanodiscus binderanus*	19 %
Peridinium spp.	19	*Peridinium* spp.	13
Stephanodiscus minutus	6.5	*Stephanodiscus minutus*	11
flagellate #1	6.5	*Melosira islandica*	8.9
Melosira islandica	6.4	flagellate #1	6.8
Asterionella formosa	4.8	*Scenedesmus bicellularis*	5.3

mean total estimated carbon density = 165 μg-C/1

Summary of patterns based on estimated carbon density
(Figs. 7a, 7b, 9a, 37; Table 8)

Region A — dominated by *Stephanodiscus binderanus* (over 50% of estimated carbon); located on SE shore; *Stephanodiscus minutus* also peaks in this region; highest estimated carbon of all regions

Region B — high densities of *Peridinium* spp., *Ankistrodesmus falcatus*, flagellate #1; stations located in NE and south-central shore; very high estimated carbon density

Region C — high density of flagellate #1; includes stations with high densities of some diatoms (e.g. *Melosira islandica, Nitzschia bacata, Nitzschia* sp. #2); located in north

Region D — low total density, but high densities of *Nitzschia dissipata, Stephanodiscus minutus*, and at some stations *Surirella angusta;* located in west central part

Region E — low densities of most taxa; located in east central part and near Niagara River

Summary of patterns based on percent estimated carbon
(Figs. 8a, 8b, 9b; Table 9)

Region A — dominated by high percentage of *Stephanodiscus binderanus;* high percentage for *Nitzschia acicularis;* located along SE shore (see region A above)

Region a — somewhat lower percentages of taxa of region A, plus high percentage of flagellate #1 at most stations; located along northern shore

Region B — dominated by *Peridinium* spp.; located in NE and SW (see region B above)

Region C — mixture of taxa (e.g. *Stephanodiscus minutus, Scenedesmus bicellularis, Stephanodiscus hantzschii, Surirella angusta)* located in mid-lake area

Region c — like region C with some characteristics of region A; high percentage of *Melosira islandica*

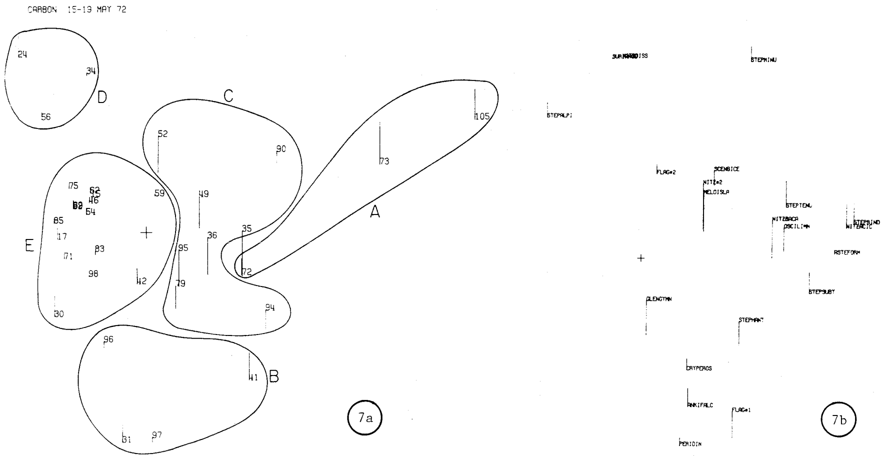


FIG. 7. Ordination of stations and taxa for cruise #1 based on PCA of estimated carbon density. See also Fig. 9a and Table 8. (a) ordination of stations based on PCA scores (b) ordination of stations based on PCA loadings

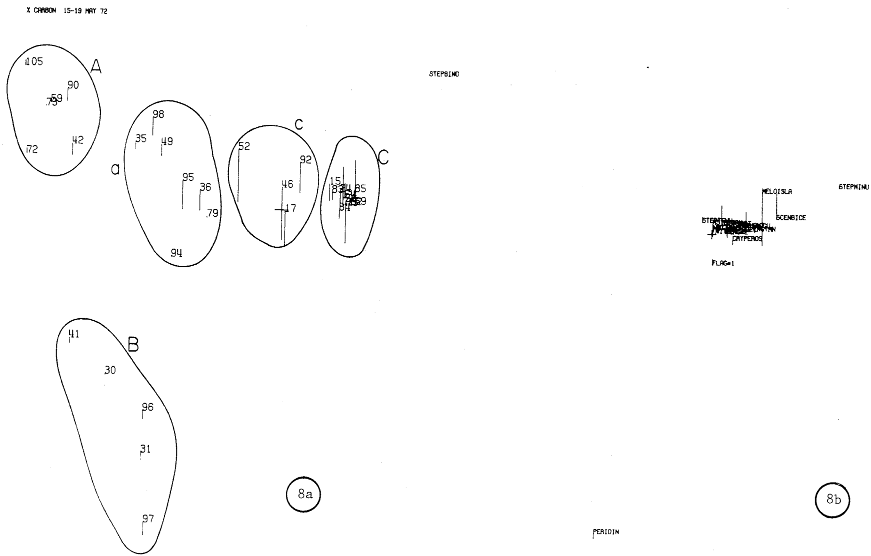


FIG. 8. Ordination of stations and taxa for cruise #1 based on PCA of estimated % carbon density. See also Fig. 9b and Table 9. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

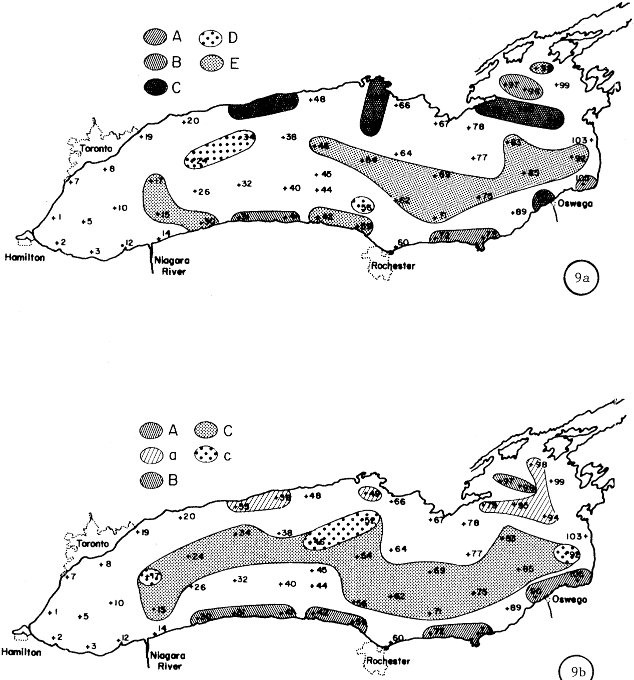


FIG. 9. Geographic location of regions determined by PCA of cruise #1.
(a) regions based on PCA of estimated carbon density. See Fig. 7 and Table 8.
(b) regions based on PCA of estimated % carbon density. See Fig. 8 and Table 9.

TABLE 8. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #1. See Figs. 7, 9a.

15-19 May 72	Grand 33	A 3	B 4	C 8	D 3	E 15	F-stat
Ankistrodesmus falcatus	.458	.535	1.664	.333	.060	.268	19.779 **
	3.755	.083	1.706	.237	.030	.445	8.5,4
Ankistrodesmus setigerus	.000						
	.000						
Asterionella formosa	7.858	17.104	9.432	11.696	3.857	4.343	6.345
	24.272	6.834	10.053	5.173	.384	3.404	7.7,4
Cryptomonas erosa	2.960	3.203	7.006	2.402	1.868	2.349	1.712
	11.209	2.887	3.092	1.914	2.015	1.877	6.4,4
Glenodinium, Gymnodinium spp.	3.377	1.472	4.367	4.794	2.142	2.985	2.818
	8.634	1.159	2.115	1.810	3.710	2.126	7.0,4
Diatoma tenue var. elongatum	.838	3.280	.498	1.806	.000	.091	2.372
	7.972	4.169	.394	1.967	.000	.166	8.5,3
flagellate #1	10.688	10.929	23.887	20.783	2.271	3.421	9.115 *
	39.882	4.717	8.564	12.233	1.367	1.291	6.0,4
flagellate #2	.948	1.586	.749	.639	1.762	.875	.397
	3.613	1.681	1.044	.703	1.720	1.093	6.3,4
Gloeocystis planctonica	.456	2.114	.998	.126	.000	.248	1.130
	3.909	1.627	1.923	.235	.000	.659	9.1,3
Lagerheimia ciliata	.000						
	.000						
Melosira islandica	10.602	9.068	5.919	20.276	8.144	7.489	2.597
	41.056	3.389	3.040	10.709	1.769	6.223	8.7,4
Nitzschia acicularis	.127	.643	.128	.121	.000	.053	2.922
	.965	.291	.219	.103	.000	.082	9.0,3
Nitzschia bacata	1.364	2.182	.563	3.401	.818	.436	3.978
	7.365	1.331	.454	2.092	.738	.336	5.9,4
Nitzschia dissipata	.309	.347	.052	.319	.885	.250	50.822 **
	.989	.080	.000	.181	.104	.208	6.6,4
Nitzschia sp. #2	.999	.349	.000	2.486	1.047	.593	2.507
	5.235	.604	.000	1.552	1.047	.652	8.7,3
Oocystis spp.	.121	.000	.249	.187	.000	.100	.319
	.498	.006	.287	.258	.000	.206	21.8,2
Oscillatoria bornetii	.000						
	.000						
Oscillatoria limnetica	.694	1.646	.374	1.496	.349	.229	3.355
	3.292	1.225	.259	.980	.377	.159	5.8,4
Phacotus lenticularis	.000						
	.000						
Peridinium spp.	31.114	34.424	166.080	17.378	3.310	7.348	5.721 *
	312.795	15.522	101.385	16.265	1.517	12.782	7.8,4
Scenedesmus bicellularis	4.764	5.845	3.419	5.699	3.696	4.622	2.159
	8.929	1.134	1.085	2.188	2.243	2.659	7.8,4
S. quadricauda var. quadrispina	.000						
	.000						
Staurastrum paradoxum	.000						
	.000						
Stephanodiscus alpinus	.568	.074	.000	.028	3.531	.515	2.615
	6.179	.127	.000	.078	2.304	.772	8.4,3
Stephanodiscus binderanus	48.749	236.645	42.377	56.999	1.063	13.007	8.697 **
	323.702	86.566	44.438	42.246	.563	31.863	7.6,4
Stephanodiscus hantzschii	3.898	4.852	4.804	6.013	1.949	2.726	5.153 *
	11.125	1.188	4.436	2.676	.673	1.829	8.1,4
Stephanodiscus minutus	10.721	21.779	2.645	10.696	15.777	9.664	9.314 **
	33.040	13.462	2.018	5.575	3.708	4.234	6.9,4
Stephanodiscus subtilis	6.098	22.285	7.418	5.661	.744	3.812	6.893 *
	31.531	9.043	6.429	9.369	.661	2.827	7.7,4
Stephanodiscus tenuis	2.912	22.776	.444	2.302	.323	.442	1.076
	47.005	21.006	.155	3.982	.323	.403	7.0,4
Surirella angusta	1.656	1.328	.498	1.743	4.839	1.347	7.050 *
	5.693	1.185	.273	1.295	1.479	1.018	6.9,4
Synedra ostenfeldii	.113	.867	.000	.142	.000	.000	.554
	1.545	.790	.000	.172	.000	.000	16.6,1
Ulothrix subconstricta	.207	1.506	.000	.207	.000	.044	.681
	3.525	1.818	.000	.393	.000	.171	13.9,2
total algal carbon	164.501	425.021	301.795	193.734	64.248	80.246	11.662
	541.344	128.415	134.862	60.932	19.117	48.604	7.4,4

TABLE 9. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #1. See Figs. 8, 9b.

15-19 May 72	Grand 33	A 6	a 7	B 5	C 11	c 4	F-stat
Ankistrodesmus falcatus	.277	.293	.177	.671	.207	.131	.738
	1.942	.350	.127	.757	.158	.136	10.6,4
Ankistrodesmus setigetus	.000						
	.000						
Asterionella formosa	5.244	4.881	5.159	4.645	4.919	7.580	2.260
	10.001	1.495	1.810	3.771	3.367	1.400	11.8,4
Cryptomonas erosa	2.631	.670	1.477	2.203	3.275	6.356	4.314 *
	12.536	.458	.801	2.157	2.486	5.150	10.3,4
Glenodinium, Gymnodinium spp.	3.426	1.273	2.540	1.538	6.776	1.357	3.801 *
	14.581	1.238	1.323	1.561	4.276	1.885	11.5,4
Diatoma tenue var. elongatum	.366	.352	1.084	.260	.043	.150	2.239
	3.238	.569	1.211	.237	.141	.115	10.8,4
flagellate #1	6.768	3.009	12.412	8.428	5.351	4.348	4.587 *
	20.841	1.530	6.485	4.106	2.681	3.180	10.6,4
flagellate #2	1.054	.234	.393	.387	2.367	.663	2.206
	6.688	.302	.453	.494	2.219	1.043	11.1,4
Gloeocystis planctonica	.151	.608	.029	.223	.000	.000	2.671
	1.167	.419	.076	.486	.000	.000	18.6,2
Lagerheimia ciliata	.000						
	.000						
Melosira islandica	8.895	4.349	9.438	1.919	9.261	22.479	16.112 **
	28.177	3.006	4.209	.917	5.871	6.200	10.8,4
Nitzschia acicularis	.061	.131	.051	.031	.054	.025	5.701 **
	.210	.033	.046	.055	.083	.051	11.4,4
Nitzschia bacata	.955	.421	1.956	.186	.774	1.459	5.726 **
	3.637	.191	1.244	.187	.645	.885	11.3,4
Nitzschia dissipata	.353	.142	.175	.016	.709	.424	9.287 **
	1.677	.124	.112	.012	.570	.272	10.1,4
Nitzschia sp. #2	.888	.414	1.062	.000	1.175	1.611	3.557 *
	4.494	.473	.970	.000	1.466	.477	18.9,3
Oocystis spp.	.115	.047	.128	.080	.122	.222	.349
	1.339	.114	.163	.117	.404	.444	11.4,4
Oscillatoria bornetii	.000						
	.000						
Oscillatoria limnetica	.501	.242	.955	.095	.534	.512	10.195 *
	2.087	.237	.719	.066	.345	.150	11.4,4
Phacotus lenticularis	.000						
	.000						
Peridinium spp.	13.132	8.987	8.532	51.636	3.544	5.640	26.892 **
	66.869	5.120	6.541	9.599	1.916	3.082	9.5,4
Scenedesmus bicellularis	5.326	1.739	2.683	.987	11.154	4.726	11.352 **
	22.139	.560	1.350	.557	5.882	1.684	11.5,4
S. quadricauda var. quadrispina	.000						
	.000						
Staurastrum paradoxum	.000						
	.000						
Stephanodiscus alpinus	.939	.007	.020	.000	2.002	2.196	2.978
	10.030	.017	.053	.000	3.049	1.500	14.1,3
Stephanodiscus binderanus	19.327	52.674	25.790	15.510	1.257	12.458	174.825 **
	59.796	4.429	6.659	10.435	1.361	5.454	8.8,4
Stephanodiscus hantzschii	3.295	1.267	3.836	1.197	4.731	4.066	10.156 **
	9.874	.437	1.860	1.090	2.392	1.247	10.6,4
Stephanodiscus minutus	11.137	5.479	4.360	.728	21.718	15.398	100.507 **
	27.116	1.722	1.611	.347	3.772	3.032	10.5,4
Stephanodiscus subtilis	3.974	4.660	3.101	2.071	5.634	2.287	2.335
	12.400	2.363	3.642	1.732	4.131	1.012	13.0,4
Stephanodiscus tenuis	1.138	3.437	.470	.170	1.063	.271	3.278
	10.528	3.789	.437	.097	1.012	.408	10.6,4
Surirella angusta	2.057	.486	.634	.177	4.524	2.469	8.753 **
	9.240	.412	.727	.188	2.653	1.472	11.1,4
Synedra ostenfeldii	.033	.092	.078	.000	.000	.000	.011
	.285	.133	.098	.000	.000	.000	72.8,1
Ulothrix subconstricta	.066	.146	.185	.000	.000	.000	.019
	.651	.263	.234	.000	.000	.000	81.5,1
total algal carbon	164.501	323.503	175.991	262.562	55.705	82.509	14.406
	541.344	144.580	47.873	146.073	15.154	45.169	8.8,4

CRUISE 2   12-16 JUNE 1972

Most abundant taxa on the basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
Stephanodiscus binderanus	38 %	*Stephanodiscus binderanus*	29 %
Stephanodiscus minutus	8.6	*Stephanodiscus minutus*	11
Melosira islandica	7.5	*Melosira islandica*	9.3
flagellate #1	6.8	flagellate #1	8.7
Asterionella formosa	6.1	*Asterionella formosa*	6.9
Stephanodiscus subtilis	5.2	*Scenedesmus bicellularis*	5.9

mean total estimated carbon density = 180 μg-C/l

Summary of patterns based on estimated carbon density
(Figs. 10a, 10b, 12a, 38; Table 10)

Regions A and a	dominated by *Stephanodiscus binderanus;* high density of *Melosira islandica* and low of flagellate #2; stronger pattern in region A than region a; region A located mainly along NW shoreline and region a is adjacent to it
Region B	similar to region A and close to it geographically; high densities of *Stephanodiscus binderanus, Melosira islandica, Asterionella formosa, Synedra ostenfeldii,* and flagellate #1
Regions C and c	high densities of *Stephanodiscus minutus, Stephanodiscus subtilis,* flagellate #1, *Cryptomonas erosa;* densities higher in region C; located in NE mainly
Region D	low algal densities; located in south central part of lake

Summary of patterns based on percent estimated carbon
(Figs. 11a, 11b, 12b; Table 11)

Regions A and a	dominated by high percentages of *Stephanodiscus binderanus;* located along NW shore and in east
Region B	high percentage of flagellate #1 and also *Glenodinium* spp., *Gymnodinium* spp., *Nitzschia acicularis, N. dissipata, Gloeocystis planctonica*; stations scattered mainly along southern shore
Regions C and c	high percentage of *Melosira islandica, Scenedesmus bicellularis, Asterionella formosa;* located in west central part of lake
Regions D and d	high percentages of *Stephanodiscus minutus* and *S. subtilis;* region d also high in *Scenedesmus bicellularis* and *Asterionella formosa;* located in eastern half

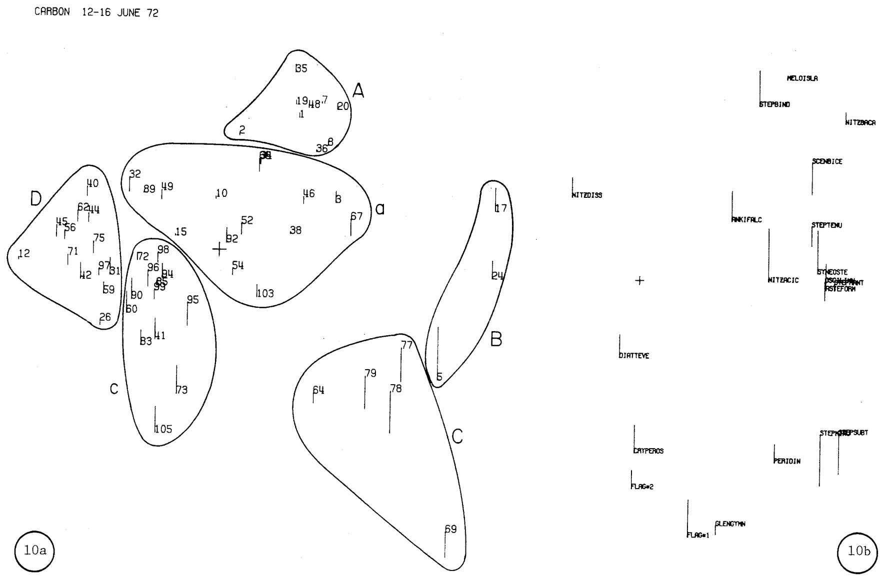


FIG. 10. Ordination of stations and taxa for cruise #2 based on PCA of estimated carbon density. See also Fig. 12a and Table 10. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

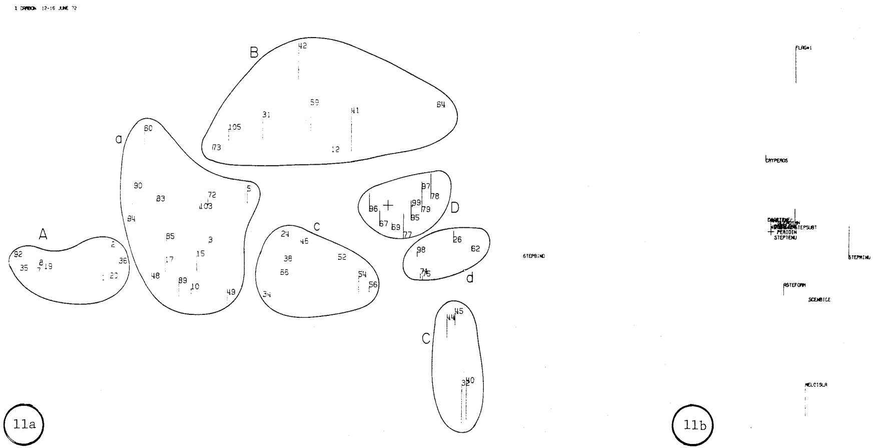


FIG. 11. Ordination of stations and taxa for cruise #2 based on PCA of estimated % carbon density. See also Fig. 12b and Table 11. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

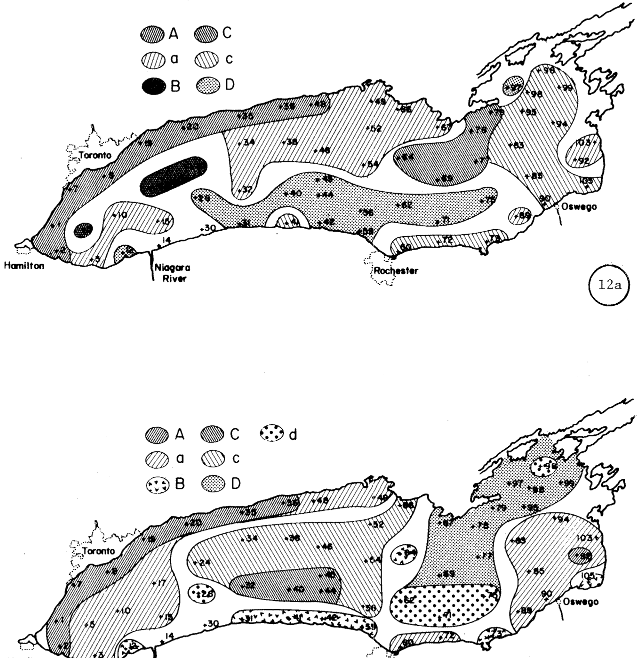


FIG. 12. Geographic location of regions determined by PCA of cruise #2.
(a) regions based on PCA of estimated carbon density. See Fig. 10 and Table 10.
(b) regions based on PCA of estimated % carbon density. See Fig. 11 and Table 11.

TABLE 10. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #2. See Figs. 10, 12a.

12-16 Jun 72	Grand 58	A 9	a 15	B 3	C 5	c 13	D 13	F-stat
Ankistrodesmus falcatus	1.190 5.257	2.017 1.475	1.012 1.209	2.115 .622	1.005 .504	1.058 .736	.815 1.171	2.059 14.5,5
Ankistrodesmus setigerus	.000 .000							
Asterionella formosa	11.030 49.173	10.871 4.393	14.479 8.699	39.154 8.759	12.627 8.268	7.004 4.193	4.082 2.438	12.949 ** 12.2,5
Cryptomonas erosa	8.44 111.294	2.936 2.802	3.897 5.387	7.206 1.601	11.370 5.840	23.959 29.999	1.170 1.967	8.448 ** 14.1,5
Glenodinium, Gymnodinium spp.	1.347 6.626	.669 .703	1.272 .841	1.606 .724	3.012 2.130	1.575 .938	.973 .650	2.184 12.9,5
Diatoma tenue var. elongatum	2.511 20.554	.969 .958	2.442 5.322	2.325 .144	.947 .719	5.998 6.756	.814 2.502	7.086 ** 20.2,5
flagellate #1	12.291 49.506	4.089 1.364	7.430 4.581	28.692 11.155	23.613 15.153	18.943 12.630	8.786 10.837	7.661 ** 12.1,5
flagellate #2	.655 5.992	.196 .164	.276 .357	1.028 .367	1.093 .527	1.105 .961	.705 1.616	6.079 ** 12.8,5
Gloeocystis planctonica	1.379 6.725	1.974 1.395	1.188 1.405	2.615 1.738	2.417 2.023	1.617 1.719	.263 .498	4.892 * 12.0,5
Lagerheimia ciliata	.000 .000							
Melosira islandica	13.428 41.056	25.020 9.834	17.816 8.602	23.676 14.357	9.521 9.154	7.866 6.265	5.038 5.190	8.150 ** 12.4,5
Nitzschia acicularis	.330 1.475	.410 .225	.337 .300	1.078 .592	.125 .093	.332 .312	.170 .264	3.728 * 13.9,5
Nitzschia bacata	1.372 4.705	3.182 1.126	1.527 .959	2.796 .718	1.555 1.323	.645 .433	.268 .348	16.878 ** 12.3,5
Nitzschia dissipata	.119 .677	.168 .140	.097 .065	.052 .090	.021 .029	.156 .188	.124 .139	4.361 * 14.1,5
Nitzschia sp. #2	.614 2.617	1.280 .911	.838 .880	.872 .800	.523 .523	.362 .393	.121 .314	3.738 * 12.4,5
Oocystis spp.	.210 2.739	.207 .329	.133 .228	.498 .498	.498 .610	.249 .761	.086 .186	.818 12.2,5
Oscillatoria bornetii	.330 2.868	.531 .694	.510 1.013	.319 .552	.191 .427	.294 .718	.074 .265	1.067 12.7,5
Oscillatoria limnetica	3.029 12.420	3.841 2.013	3.911 3.053	4.639 4.668	6.824 3.769	2.072 .975	.576 .559	10.877 ** 11.8,5
Phacotus lenticularis	.000 .000							
Peridinium spp.	3.818 40.713	.441 1.007	3.442 4.517	21.184 17.493	11.519 16.977	2.521 3.208	.917 1.179	2.615 12.3,5
Scenedesmus bicellularis	7.053 21.690	10.665 2.767	7.685 3.998	10.422 7.265	11.142 6.647	3.876 2.366	4.650 2.883	7.463 ** 12.4,5
S. quadricauda var. quadrispina	.000 .000							
Staurastrum paradoxum	.000 .000							
Stephanodiscus alpinus	.038 .662	.123 .224	.000 .000	.074 .127	.044 .099	.034 .083	.017 .061	.436 13.6,4
Stephanodiscus binderanus	69.191 321.788	198.338 69.805	62.358 75.453	115.486 59.752	16.972 8.295	60.663 45.178	5.595 7.984	17.367 ** 12.7,5
Stephanodiscus hantzschii	.801 2.726	1.080 .440	.742 .698	1.730 .293	1.513 .669	.788 .657	.203 .176	19.766 ** 12.5,5
Stephanodiscus minutus	15.656 74.432	11.797 2.067	13.550 8.342	22.707 11.225	59.063 14.367	11.922 9.814	6.168 4.165	13.091 ** 12.4,5
Stephanodiscus subtilis	9.390 53.692	10.271 3.673	7.605 4.611	12.270 7.159	35.948 15.017	7.265 4.377	2.088 1.121	16.225 ** 11.7,5
Stephanodiscus tenuis	1.181 4.038	1.723 1.009	1.820 1.328	1.077 .918	2.100 .412	.522 .528	.398 .450	13.052 ** 13.1,5
Surirella angusta	.034 .569	.063 .126	.038 .147	.000 .000	.000 .000	.022 .079	.044 .107	.173 53.9,3
Synedra ostenfeldii	.116 1.057	.181 .176	.125 .168	.732 .282	.049 .073	.056 .070	.013 .031	5.946 ** 11.9,5
Ulothrix subconstricta	.101 2.534	.037 .110	.073 .231	.514 .890	.507 1.133	.025 .092	.000 .000	.382 13.2,4
total algal carbon	179.994 446.493	319.492 80.881	168.701 87.235	317.616 69.569	232.974 40.273	174.574 68.358	49.738 23.689	38.413 12.4,5

TABLE 11. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #2. See Figs. 11, 12b.

12-16 Jun 72	Grand 58	A 9	a 15	B 8	C 4	c 8	D 9	d 5	F-stat
Ankistrodesmus falcatus	.797	.688	.715	1.780	.407	.673	.439	.825	1.865
	4.437	.825	.695	1.664	.292	.263	.187	.431	17.2,6
Ankistrodesmus setigetus	.000								
	.000								
Asterionella formosa	6.915	3.484	8.368	3.199	11.594	9.944	4.539	10.365	5.499 **
	21.214	1.399	5.302	2.014	8.743	3.876	2.125	5.716	16.5,6
Cryptomonas erosa	4.263	.994	5.664	10.922	.663	1.363	4.938	1.599	3.798 *
	36.195	1.072	5.489	11.597	1.325	1.618	3.336	2.489	17.6,6
Glenodinium, Gymnodinium spp.	1.209	.238	.644	2.719	1.462	1.014	1.109	2.517	5.696 **
	10.615	.204	.397	3.389	.851	.749	.596	2.507	15.8,6
Diatoma tenue var. elongatum	1.292	.600	2.515	.629	.078	.254	2.154	1.009	2.850
	9.744	1.080	3.184	.617	.156	.452	3.029	2.255	19.8,6
flagellate #1	8.713	1.486	7.317	26.164	4.678	5.629	7.798	7.804	19.403 **
	43.027	.817	6.556	12.783	1.784	2.708	2.398	1.995	16.6,6
flagellate #2	.598	.056	.305	.848	.409	.178	.316	3.380	8.859 **
	14.816	.055	.258	.393	.501	.207	.157	6.404	15.7,6
Gloeocystis planctonica	.718	.691	.958	1.021	.000	.685	.735	.160	3.737 **
	3.197	.707	.988	.548	.000	.473	.755	.221	29.1,5
Lagerheimia ciliata	.000								
	.000								
Melosira islandica	9.331	7.055	7.232	3.475	35.090	13.373	4.949	9.911	8.044 **
	44.044	2.856	5.297	5.054	9.963	4.301	3.021	6.601	16.6,6
Nitzschia acicularis	.209	.104	.190	.558	.071	.355	.077	.011	9.282 **
	.988	.055	.158	.345	.142	.210	.155	.026	18.0,6
Nitzschia bacata	.737	.929	.677	.738	.238	1.003	.709	.589	1.078
	2.529	.459	.517	.684	.477	.614	.736	1.099	17.0,6
Nitzschia dissipata	.126	.039	.080	.334	.210	.065	.038	.281	6.524 **
	1.835	.034	.083	.627	.049	.049	.051	.377	17.0,6
Nitzschia sp. #2	.366	.388	.391	.117	.631	.536	.110	.624	1.782
	2.589	.411	.378	.227	.797	.712	.173	1.122	16.3,6
Oocystis spp.	.132	.081	.035	.276	.000	.070	.406	.000	1.114
	2.169	.105	.093	.322	.000	.143	.696	.000	35.7,4
Oscillatoria bornetii	.155	.125	.311	.000	.000	.236	.148	.000	.354
	1.559	.202	.425	.000	.000	.547	.337	.000	57.5,3
Oscillatoria limnetica	1.783	1.141	1.484	1.695	.836	3.456	2.499	.768	3.687 *
	7.063	.796	1.469	2.228	1.206	2.258	1.388	.464	18.1,6
Phacotus lenticularis	.000								
	.000								
Peridinium spp.	2.077	.466	2.604	1.276	.786	1.652	2.583	5.484	1.810
	15.203	1.031	4.121	1.090	1.572	1.647	4.668	4.220	17.2,6
Scenedesmus bicellularis	5.854	3.228	3.281	1.501	14.470	6.014	5.507	18.741	10.052 **
	24.886	2.088	2.279	1.021	5.582	3.027	1.984	8.851	16.4,6
S. quadricauda var. quadrispina	.000								
	.000								
Staurastrum paradoxum	.000								
	.000								
Stephanodiscus alpinus	.026	.027	.011	.028	.000	.000	.056	.000	.420
	.239	.062	.030	.080	.000	.000	.090	.000	46.7,3
Stephanodiscus binderanus	28.646	63.225	42.933	21.142	.665	23.065	8.252	3.577	171.738 **
	72.070	7.547	5.761	10.525	1.331	6.163	3.691	3.124	20.0,6
Stephanodiscus hantzschii	.493	.315	.411	.225	.655	.396	.826	.915	3.214 *
	1.780	.213	.265	.205	.412	.243	.390	.597	16.6,6
Stephanodiscus minutus	10.699	3.431	4.663	5.486	15.398	12.963	23.766	19.326	30.448 **
	30.473	.900	1.307	7.891	4.224	3.180	6.172	5.291	15.7,6
Stephanodiscus subtilis	5.369	3.161	3.184	3.452	3.996	5.496	12.830	6.434	7.126 **
	18.671	.981	1.614	2.359	1.507	2.217	4.622	2.404	16.8,6
Stephanodiscus tenuis	.811	.391	.512	.448	1.572	1.414	.700	1.674	2.813 *
	3.286	.230	.574	.385	.710	1.200	.494	1.525	16.3,6
Surirella angusta	.040	.026	.029	.000	.000	.000	.000	.327	.343
	.931	.054	.078	.000	.000	.000	.000	.455	54.2,2
Synedra ostenfeldii	.057	.044	.095	.030	.000	.095	.028	.043	1.397
	.395	.060	.126	.061	.000	.066	.036	.095	25.3,5
Ulothrix subconstricta	.046	.009	.032	.194	.000	.068	.000	.000	.372
	1.441	.027	.101	.505	.000	.192	.000	.000	47.1,3
total algal carbon	179.994	345.760	203.530	130.864	43.712	152.549	176.713	48.474	30.626
	446.493	79.280	72.016	93.578	12.118	70.904	72.311	28.385	20.4,6

CRUISE 3 10-14 JULY 1972

Most abundant taxa on the basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
Stephanodiscus subtilis	13 %	*Diatoma tenue* var. *elongatum*	12 %
Diatoma tenue var. *elongatum*	12	flagellate #1	12
Stephanodiscus minutus	10	*Stephanodiscus subtilis*	11
flagellate #1	10	*Stephanodiscus minutus*	9.3
Peridinium spp.	8.4	*Glenodinium, Gymnodinium* spp.	9.3
Stephanodiscus binderanus	6.2	*Peridinium* spp.	8.6

mean total estimated carbon density = 50 μg-C/l

Summary of patterns based on estimated carbon density
(Figs. 13a, 13b, 15a, 39; Table 12)

This cruise is characterized by low density at all stations except two (#14, #75) where densities are extremely high. These two stations dominate the pattern (see Fig. 15a).

Region A	consists of one station with extremely high total density (#75 in east-central) dominated by diatoms: *Stephanodiscus subtilis, Diatoma tenue* var. *elongatum, S. binderanus, S. minutus, Asterionella formosa*
Region B	one station with highest density in lake (#14 near Niagara River); high densities of *Gloeocystis planctonica, Stephanodiscus subtilis,* flagellate #1
Region AB	two stations off Toronto somewhat similar to both regions A and B but with lower densities
Region C and c	low total density, lowest in region C

Summary of patterns based on percent estimated carbon
(Figs. 14a, 14b, 15b; Table 13)

Region A and a	dominated by high percentages of *Stephanodiscus subtilis;* stations scattered but mainly in SW
Region B	dominated by *Glenodinium* spp., *Gymnodinium* spp., and flagellate #1; stations in three inshore locations around lake
Region C	dominated by *Peridinium* spp.; most stations in central part of lake
Region D	dominated by *Stephanodiscus minutus;* high percentage of *Stephanodiscus hantzschii;* located on periphery of region C
Region E	mix of other taxa; most stations in east

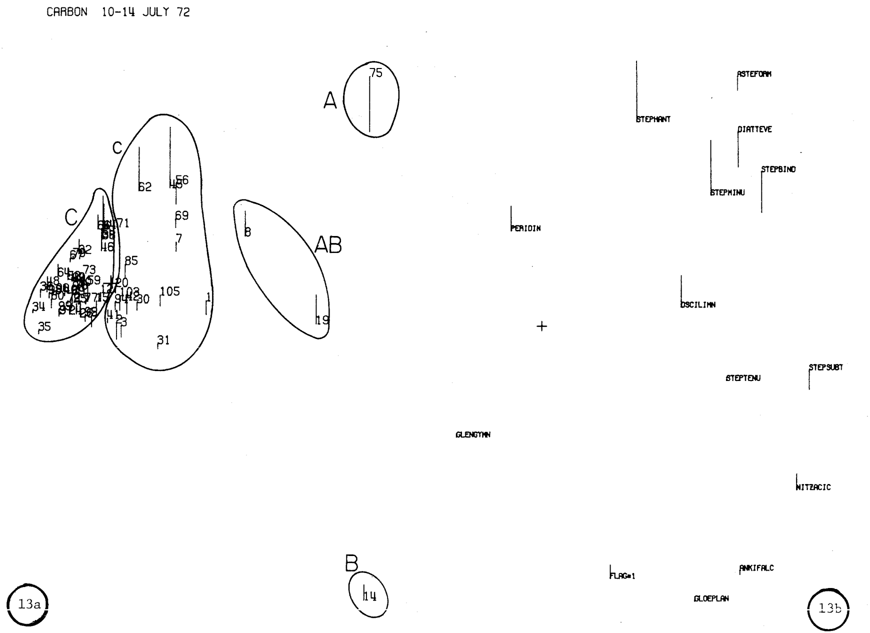


FIG. 13. Ordination of stations and taxa for cruise #3 based on PCA of estimated carbon density. See also Fig. 15a and Table 12. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

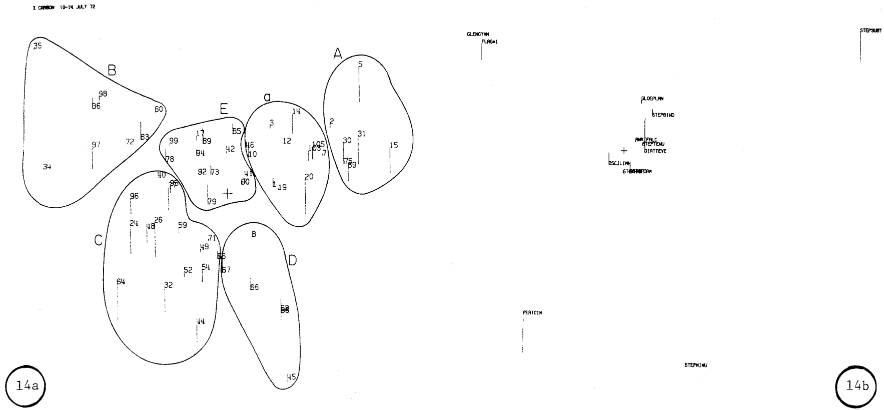


FIG. 14. Ordination of stations and taxa for cruise #3 based on PCA of estimated % carbon density. See also Fig. 15b and Table 13. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

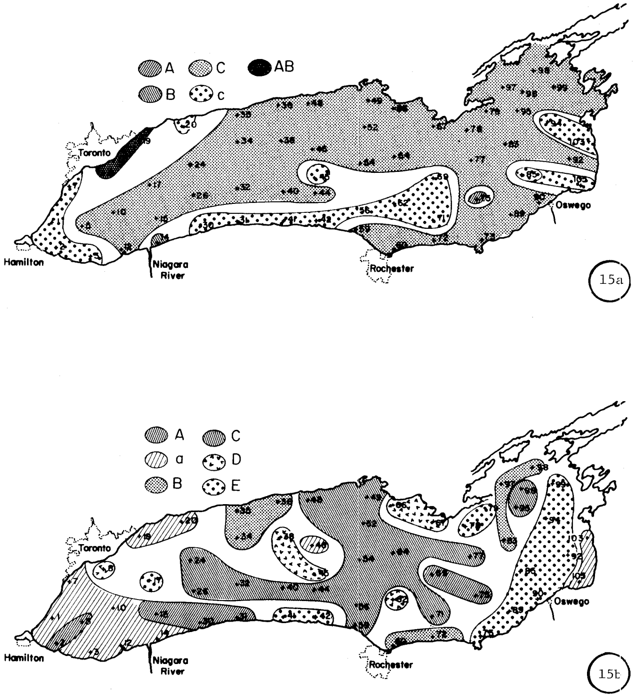


FIG. 15. Geographic location of regions determined by PCA of cruise #3.
(a) regions based on PCA of estimated carbon density. See Fig. 13 and Table 12.
(b) regions based on PCA of estimated % carbon density. See Fig. 14 and Table 13.

TABLE 12. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #3. See Figs. 13, 15a.

10-14 Jul 72	Grand 69	A 1	AB 2	B 1	C 38	c 18	F-stat
Ankistrodesmus falcatus	.394 3.755	.000	1.230 1.190	3.755	.128 .194	.699 .821	4.017 2.5,2
Ankistrodesmus setigerus	.006 .165	.000	.000 .000	.000	.004 .027	.011 .039	.237 65.7,1
Asterionella formosa	1.448 15.846	15.846	4.150 2.846	.126	.669 .902	2.068 2.932	2.697 2.6,2
Cryptomonas erosa	.000 .000						
Glenodinium, Gymnodinium spp.	2.985 11.846	1.004	3.413 1.704	4.417	3.450 2.556	1.986 1.959	2.372 2.9,2
Diatoma tenue var. elongatum	5.998 37.869	37.869	9.218 1.762	3.488	3.721 2.953	8.817 5.734	10.959 * 3.2,2
flagellate #1	4.807 24.791	1.655	4.696 .762	24.791	4.575 3.405	4.376 3.110	.057 6.6,2
flagellate #2	.000 .000						
Gloeocystis planctonica	3.047 68.805	.656	.724 .715	68.805	1.361 1.758	3.343 5.498	1.645 4.1,2
Lagerheimia ciliata	.052 .794	.000	.317 .449	.397	.036 .155	.040 .116	.314 2.6,2
Melosira islandica	.445 3.778	3.778	1.511 .712	.000	.305 .853	.462 .682	2.205 2.9,2
Nitzschia acicularis	.079 1.135	.170	.851 .401	1.021	.018 .040	.066 .076	5.920 2.6,2
Nitzschia bacata	.068 .614	.205	.511 .145	.000	.032 .101	.091 .126	9.318 2.7,2
Nitzschia dissipata	.023 .208	.000	.026 .037	.000	.019 .041	.032 .060	.279 2.8,2
Nitzschia sp. #2	.017 .523	.000	.000 .000	.000	.014 .085	.029 .123	.112 66.4,1
Oocystis spp.	.129 1.494	.000	.000 .000	.000	.105 .287	.207 .344	.596 76.4,1
Oscillatoria bornetii	.988 41.102	.956	.000 .000	.000	1.459 6.685	.159 .676	.699 102.9,1
Oscillatoria limnetica	2.245 13.767	2.843	8.754 7.089	2.993	1.890 2.028	2.195 1.513	.872 2.6,2
Phacotus lenticularis	.155 3.383	.000	.000 .000	.000	.022 .096	.470 1.045	1.622 45.7,1
Peridinium spp.	4.171 27.804	2.979	1.490 .702	.000	4.416 6.670	4.248 4.802	4.559 * 18.3,2
Scenedesmus bicellularis	.047 1.322	.054	.108 .153	.000	.031 .080	.076 .311	.338 2.6,2
S. quadricauda var. quadrispina	.020 .611	.000	.000 .000	.000	.008 .050	.051 .157	.631 49.7,1
Staurastrum paradoxum	.000 .000						
Stephanodiscus alpinus	.022 .662	.000	.000 .000	.221	.029 .117	.000 .000	.000 0,0
Stephanodiscus binderanus	3.102 32.115	32.115	9.252 .451	1.276	1.175 1.957	4.974 3.807	148.271 ** 7.8,2
Stephanodiscus hantzschii	.676 3.738	1.187	2.177 .840	.000	.576 .710	.730 1.029	2.863 2.7,2
Stephanodiscus minutus	5.036 43.249	14.107	13.921 1.575	12.808	2.970 3.773	7.476 10.282	32.128 ** 4.9,2
Stephanodiscus subtilis	6.596 46.181	46.181	10.485 8.729	41.570	2.047 3.549	11.626 8.531	8.947 2.6,2
Stephanodiscus tenuis	.797 9.530	.485	5.088 2.170	3.069	.281 .489	1.301 2.254	5.279 2.5,2
Surirella angusta	.019 .569	.009	.000 .000	.000	.015 .092	.032 .092	.198 89.5,1
Synedra ostenfeldii	.009 .163	.081	.041 .057	.000	.064 .018	.014 .042	.624 2.6,2
Ulothrix subconstricta	.551 4.296	.000	1.597 .701	.771	.223 .467	1.144 1.397	5.771 2.6,2
total algal carbon	49.751 176.949	167.910	93.644 24.607	176.949	33.545 18.363	65.456 16.692	19.895 2.7,2

TABLE 13. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #4. See Figs. 14, 15b.

10-14 Jul 72	Grand 60	A 7	a 11	B 8	C 16	D 6	E 12	F-stat
Ankistrodesmus falcatus	.745 6.923	2.102 2.538	1.522 1.227	.374 .554	.319 .583	.112 .199	.372 .564	3.498 * 22.1,5
Ankistrodesmus setigerus	.032 1.684	.000 .000	.024 .064	.210 .595	.000 .000	.000 .000	.000 .000	.151 83.0,1
Asterionella formosa	2.538 18.437	2.212 3.360	2.051 2.467	2.372 3.481	2.694 4.571	4.489 2.316	2.100 2.386	.922 21.2,5
Cryptomonas erosa	.000 .000							
Glenodinium, Gymnodinium spp.	9.259 56.823	2.979 4.911	5.570 4.910	27.635 17.957	8.967 5.959	2.210 2.008	7.968 3.985	7.026 ** 22.1,5
Diatoma tenue var. elongatum	12.400 35.340	12.439 7.057	12.061 10.611	9.969 8.920	10.665 7.516	14.644 11.520	15.498 7.271	.683 20.4,5
flagellate #1	11.976 45.063	6.652 5.222	6.070 4.725	28.349 13.407	13.002 7.266	3.999 2.274	12.200 7.343	8.603 ** 22.5,5
flagellate #2	.000 .000							
Gloeocystis planctonica	5.001 38.884	4.770 5.591	6.302 11.511	2.234 4.214	4.039 4.001	.726 .746	9.209 11.236	3.926 * 21.5,5
Lagerheimia ciliata	.083 1.637	.000 .000	.164 .281	.000 .000	.081 .325	.000 .000	.155 .471	.106 96.4,2
Melosira islandica	.724 8.020	.808 1.133	.431 .747	.143 .405	1.169 2.459	1.966 2.128	.117 .285	1.906 19.3,5
Nitzschia acicularis	.107 1.022	.211 .220	.244 .325	.000 .000	.043 .082	.136 .299	.065 .087	1.422 23.6,4
Nitzschia bacata	.136 1.737	.100 .141	.057 .130	.000 .000	.252 .506	.372 .480	.048 .167	.904 27.0,4
Nitzschia dissipata	.070 1.327	.025 .066	.086 .117	.000 .000	.108 .330	.086 .134	.072 .167	.557 29.6,4
Nitzschia sp. #2	.039 1.542	.000 .000	.000 .000	.000 .000	.000 .000	.136 .332	.128 .445	.000 153.8,1
Oocystis spp.	.311 3.865	.403 .708	.193 .380	.276 .781	.288 .972	.000 .000	.574 .863	.402 29.7,4
Oscillatoria bornetii	1.644 42.592	.081 .215	.000 .000	.530 1.498	1.892 5.175	.717 1.757	4.936 12.037	.953 23.9,4
Oscillatoria limnetica	5.471 35.975	2.119 2.044	6.395 10.344	7.169 6.654	4.005 3.690	7.840 10.459	6.217 4.657	2.063 20.6,5
Phacotus lenticularis	.244 4.503	.000 .000	.919 1.689	.000 .000	.000 .000	.000 .000	.377 .693	.193 152.2,1
Peridinium spp.	8.635 46.518	3.020 2.831	2.254 6.141	5.855 10.477	21.896 11.089	7.097 5.364	2.703 3.303	8.429 ** 21.1,5
Scenedesmus bicellularis	.104 1.705	.005 .012	.173 .511	.271 .536	.127 .274	.000 .000	.009 .032	1.188 31.2,4
S. quadricauda var. quadrispina	.064 2.176	.311 .823	.036 .119	.000 .000	.079 .316	.000 .000	.000 .000	.187 54.9,2
Staurastrum paradoxum	.000 .000							
Stephanodiscus alpinus	.100 2.812	.000 .000	.011 .038	.282 .797	.000 .000	.000 .000	.301 .823	.455 50.1,2
Stephanodiscus binderanus	5.434 43.351	6.833 7.049	6.625 5.822	2.201 2.503	3.862 4.163	2.723 4.778	9.135 12.155	1.717 20.7,5
Stephanodiscus hantzschii	1.573 8.986	.468 .423	1.576 2.553	1.419 1.511	1.531 1.363	4.537 1.381	.893 1.177	9.592 ** 21.3,5
Stephanodiscus minutus	9.284 54.902	8.869 4.426	6.204 3.079	2.325 1.528	10.369 8.701	32.319 13.505	4.025 3.080	10.370 ** 20.6,5
Stephanodiscus subtilis	10.660 50.368	37.595 8.243	20.704 6.665	1.293 1.223	2.803 2.476	5.931 4.450	4.826 4.736	38.996 ** 20.0,5
Stephanodiscus tenuis	1.432 12.290	1.749 2.531	3.962 3.407	.000 .000	.768 1.156	2.110 3.296	.432 .805	2.473 23.9,4
Surirella angusta	.042 1.546	.069 .184	.000 .000	.000 .000	.000 .000	.258 .631	.040 .138	.148 39.6,2
Synedra ostenfeldii	.016 .370	.007 .018	.019 .063	.046 .131	.014 .038	.018 .044	.000 .000	.239 25.2,4
Ulothrix subconstricta	1.144 8.387	.917 1.219	1.935 2.710	.704 1.992	.912 1.392	.940 1.696	1.255 2.479	.304 20.8,5
total algal carbon	49.751 176.949	66.311 49.675	79.061 44.356	17.493 5.555	48.040 22.561	50.949 25.217	44.663 22.510	11.094 19.8,5

CRUISE 4 21-24 AUGUST 1972

Most abundant taxa on the basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
Peridinium spp.	16 %	*Phacotus lenticularis*	17 %
Phacotus lenticularis	15	*Peridinium* spp.	16
Fragilaria crotonensis	9.8	*Fragilaria crotonensis*	9.1
Oocystis spp.	8.4	*Oocystis* spp.	8.8
Staurastrum paradoxum	6.0	*Staurastrum paradoxum*	6.3
Ulothrix subconstricta	5.3	*Ulothrix subconstricta*	4.1

mean total estimated carbon density = 82 μg-C/l

Summary of patterns based on estimated carbon density
(Figs. 16a, 16b, 18a, 40; Table 14)

Region A — high densities of *Peridinium* spp., *Oocystis* spp., *Scenedesmus quadricauda* var. *quadrispina*; located mainly in NE

Region B — higher than average densities of *Ankistrodesmus falcatus, Oocystis* spp., *Scenedesmus quadricauda* var. *quadrispina, Ulothrix subconstricta;* scattered stations in east

Region C — consists of one station (#60) near Rochester; highest density of any station for total estimated carbon, *Ulothrix subconstricta, Ankistrodesmus falcatus, Nitzschia dissipata;* high densities of *Phacotus lenticularis, Stephanodiscus subtilis*

Region D — high densities of *Phacotus lenticularis, Staurastrum paradoxum;* low total density; mainly south-central stations

Region E — low total density; located in north-central area

Summary of patterns based on percent estimated carbon
(Figs. 17a, 17b, 18b; Table 15)

Region A — high percentage of *Peridinium* spp.; located mainly in NW

Region B — high percentage of *Phacotus lenticularis;* located in west-central part

Region AB — above average percentages of *Peridinium* spp., *Phacotus lenticularis, Oocystis* spp.; located widely in NW area

Region C — high percentage of *Staurastrum paradoxum;* located along western half of southern shore

Region D — high percentage of *Ulothrix subconstricta;* located mainly near Rochester

Region AD — above average percentages of *Peridinium* spp., *Ulothrix subconstricta, Oocystis* spp.; located in east

Region BD — above average percentage of *Oocystis* spp.; located in eastern half

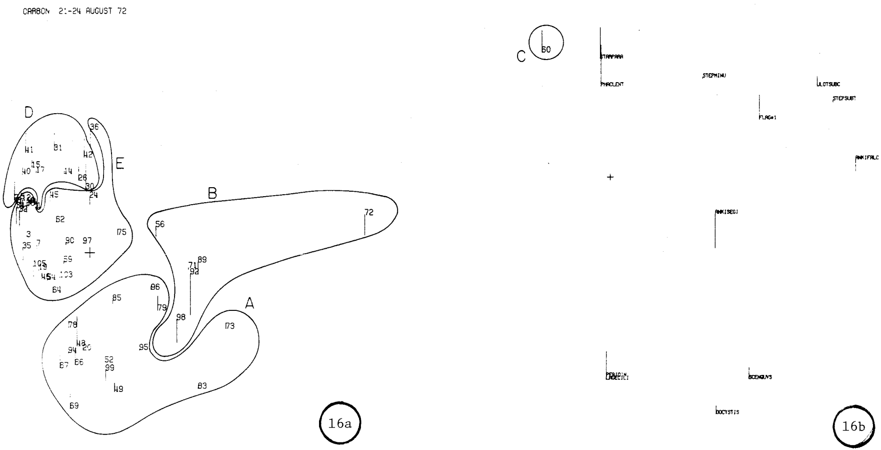


FIG. 16. Ordination of stations and taxa for cruise #4 based on PCA of estimated carbon density. See also Fig. 18a and Table 14. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

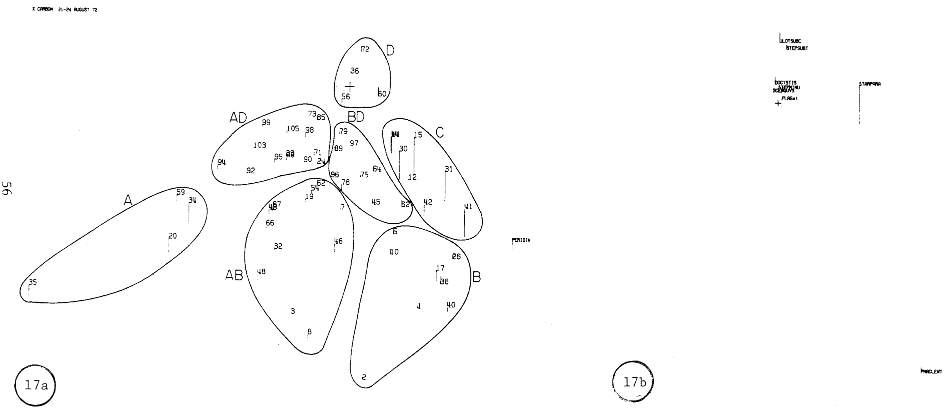


FIG. 17. Ordination of stations and taxa for cruise #4 based on PCA of estimated % carbon density. See also Fig. 18b and Table 15. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

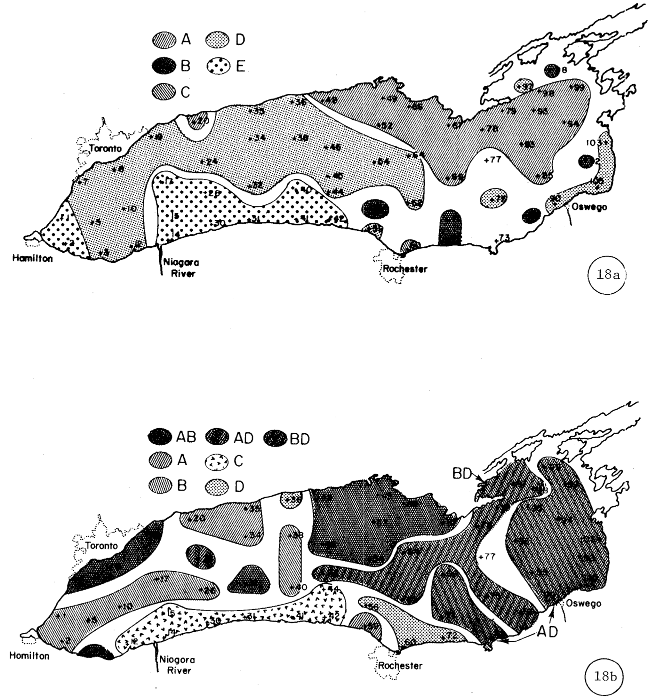


FIG. 18. Geographic location of regions determined by PCA of cruise #4.
(a) regions based on PCA of estimated carbon density. See Fig. 16 and Table 14.
(b) regions based on PCA of estimated % carbon density. See Fig. 17 and Table 15.

TABLE 14. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #4. See Figs. 16, 18a.

21-24 Aug 72	Grand 59	A 16	B 6	C 1	D 11	E 25	F-stat
Ankistrodesmus falcatus	.101 .855	.105 .134	.427 .223	.855	.031 .054	.020 .035	7.910 ** 15.0,3
Ankistrodesmus setigerus	.108 1.360	.082 .108	.584 .552	.165	.045 .057	.035 .072	2.508 16.7,3
Asterionella formosa	.301 3.647	.149 .335	.042 .103	.000	.114 .305	.553 1.097	2.003 27.5,3
Cryptomonas erosa	.000 .000						
Glenodinium, Gymnodinium spp.	.170 2.811	.000 .000	.000 .000	.402	.748 .963	.056 .213	1.807 52.2,1
Diatoma tenue var. elongatum	.065 1.370	.023 .093	.000 .000	.000	.034 .081	.125 .365	.569 59.3,2
flagellate #1	.413 2.348	.488 .669	.526 .554	1.848	.644 .699	.179 .416	2.177 16.7,3
flagellate #2	.000 .000						
Gloeocystis planctonica	1.735 6.451	3.303 2.206	1.713 1.164	1.257	1.248 1.392	.971 1.456	4.530 * 19.4,3
Lagerheimia ciliata	.235 1.905	.615 .601	.106 .192	.000	.036 .120	.121 .240	4.647 * 19.3,3
Melosira islandica	.196 5.289	.031 .126	.420 1.028	.504	.160 .395	.252 1.069	.876 15.3,3
Nitzschia acicularis	.021 .170	.035 .041	.038 .046	.170	.000 .000	.011 .028	1.701 22.8,2
Nitzschia bacata	.007 .409	.000 .000	.000 .000	.000	.000 .000	.016 .082	.000 0,0
Nitzschia dissipata	.011 .469	.003 .013	.000 .000	.469	.000 .000	.006 .023	.094 193.0,1
Nitzschia sp. #2	.009 .523	.000 .000	.000 .000	.000	.000 .000	.021 .105	.000 0,0
Oocystis spp.	6.901 19.170	11.522 3.474	9.066 1.425	6.598	4.063 1.909	4.685 3.173	24.705 ** 22.9,3
Oscillatoria bornetii	.000 .000						
Oscillatoria limnetica	.266 2.544	.103 .217	.424 .602	2.095	.272 .428	.257 .729	1.061 16.7,3
Phacotus lenticularis	12.193 49.482	10.758 7.508	6.485 3.732	30.027	21.646 11.464	9.609 5.900	5.224 ** 29.2,3
Peridinium spp.	13.060 65.538	24.142 16.121	10.758 7.172	5.958	4.875 6.623	10.407 10.776	5.919 ** 20.5,3
Scenedesmus bicellularis	.009 .540	.000 .000	.000 .000	.000	.000 .000	.022 .108	.000 0,0
S. quadricauda var. quadrispina	.959 5.190	2.390 1.264	1.374 .662	1.832	.139 .250	.269 .516	19.893 ** 17.9,3
Staurastrum paradoxum	4.950 32.176	2.939 2.591	3.309 3.382	9.900	15.525 12.817	1.782 2.723	4.286 * 16.6,3
Stephanodiscus alpinus	.004 .221	.014 .055	.000 .000	.000	.000 .000	.000 .000	.000 0,0
Stephanodiscus binderanus	.068 2.340	.106 .291	.000 .000	.000	.000 .000	.094 .468	.304 194.9,1
Stephanodiscus hantzschii	.049 1.803	.016 .039	.015 .023	.396	.012 .040	.081 .359	.294 25.1,3
Stephanodiscus minutus	.324 4.084	.255 .479	.278 .466	2.413	.169 .194	.364 .841	.498 18.8,3
Stephanodiscus subtilis	2.191 30.118	1.167 1.852	10.015 11.159	24.912	.811 .646	.666 .890	1.616 16.6,3
Stephanodiscus tenuis	.036 .898	.050 .202	.000 .000	.000	.088 .244	.013 .065	.473 32.5,2
Surirella angusta	.000 .000						
Synedra ostenfeldii	.004 .081	.000 .000	.014 .033	.000	.000 .000	.007 .023	.078 30.7,1
Ulothrix subconstricta	4.358 96.945	3.119 2.726	7.271 3.273	96.945	.531 .698	2.432 3.409	12.713 ** 17.4,3
total algal carbon	82.057 235.626	106.312 31.935	95.752 29.247	235.626	74.834 18.687	60.282 36.084	6.516 19.2,3

TABLE 15. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #4. See Figs. 17, 18b.

21-24 Aug 72	Grand 59	A 4	B 8	AB 12	C 8	D 4	AD 14	BD 9	F-stat
Ankistrodesmus falcatus	.110	.024	.010	.017	.053	.420	.190	.148	3.067 *
	.852	.047	.028	.035	.064	.257	.236	.262	15.7,6
Ankistrodesmus setigerus	.148	.173	.128	.102	.027	.184	.290	.090	1.404
	2.354	.242	.114	.168	.059	.254	.645	.124	15.7,6
Asterionella formosa	.877	4.303	.883	.259	.057	3.448	.058	1.035	.943
	17.211	8.606	1.888	.484	.162	6.897	.148	2.319	14.6,6
Cryptomonas erosa	.000								
	.000								
Glenodinium, Gymnodinium spp.	.264	.100	1.324	.000	.552	.043	.000	.000	1.088
	4.062	.200	1.885	.000	.761	.085	.000	.000	30.2,3
Diatoma tenue var. elongatum	.137	.068	.638	.136	.059	.142	.000	.000	.281
	3.818	.136	1.362	.471	.121	.285	.000	.000	22.0,4
flagellate #1	.547	.076	.622	.235	.628	.568	.672	.831	2.305
	4.905	.094	1.280	.406	.675	.717	1.282	.958	18.2,6
flagellate #2	.000								
	.000								
Gloeocystis planctonica	2.219	.639	1.484	3.892	1.598	.849	2.427	2.181	2.230
	11.222	.764	1.262	3.597	1.868	1.027	1.979	2.300	18.5,6
Lagerheimia ciliata	.324	.101	.029	.832	.073	.000	.259	.478	2.398
	2.713	.119	.081	.937	.159	.000	.633	.555	24.9,5
Melosira islandica	.526	.000	.137	.035	.178	6.096	.266	.000	.456
	24.172	.000	.387	.121	.503	12.051	.809	.000	23.9,4
Nitzschia acicularis	.027	.014	.000	.019	.000	.190	.019	.030	.413
	.519	.028	.000	.037	.000	.221	.027	.052	21.3,4
Nitzschia bacata	.032	.000	.000	.000	.000	.467	.000	.000	.000
	1.870	.000	.000	.000	.000	.935	.000	.000	0,0
Nitzschia dissipata	.010	.026	.000	.004	.000	.109	.000	.000	.505
	.238	.052	.000	.013	.000	.127	.000	.000	24.6,2
Nitzschia sp. #2	.041	.000	.000	.000	.000	.598	.000	.000	.000
	2.392	.000	.000	.000	.000	1.196	.000	.000	0,0
Oocystis spp.	8.792	3.236	6.334	12.002	5.611	5.107	10.238	11.380	8.810 **
	24.524	1.201	3.587	6.571	1.293	4.683	3.173	6.567	17.2,6
Oscillatoria bornetii	.000								
	.000								
Oscillatoria limnetica	.230	.661	.000	.000	.428	.613	.266	.145	.481
	2.534	1.250	.000	.030	.539	.760	.521	.292	19.8,4
Phacotus lenticularis	17.285	6.305	40.906	21.610	18.238	4.427	6.547	16.976	32.449 **
	51.570	2.396	6.790	8.004	7.020	5.745	3.842	5.779	17.1,6
Peridinium spp.	15.890	52.095	8.351	24.636	2.902	2.126	18.437	8.538	28.140 **
	74.862	15.352	7.406	7.007	2.244	2.830	5.868	3.178	16.4,6
Scenedesmus bicellularis	.042	.000	.000	.000	.000	.616	.000	.000	.000
	2.466	.000	.000	.000	.000	1.233	.000	.000	0,0
S. quadricauda var. quadrispina	.998	.410	.000	1.104	.296	.921	1.616	1.703	3.147 *
	4.976	.633	.000	1.390	.332	.702	1.517	1.274	19.1,5
Staurastrum paradoxum	6.337	6.885	4.403	3.775	26.173	3.293	1.396	2.638	5.003 **
	43.091	6.423	6.133	3.825	12.968	2.691	1.661	2.791	15.0,6
Stephanodiscus alpinus	.003	.000	.000	.000	.000	.000	.012	.000	.000
	.165	.000	.000	.000	.000	.000	.044	.000	0,0
Stephanodiscus binderanus	.205	.000	.000	.000	.000	2.673	.101	.000	.144
	10.691	.000	.000	.000	.000	5.346	.256	.000	48.1,1
Stephanodiscus hantzschii	.160	.022	.036	.021	.000	2.123	.013	.014	.233
	8.239	.044	.101	.073	.000	4.078	.031	.033	17.6,5
Stephanodiscus minutus	.595	.619	.235	.213	.210	5.161	.154	.413	.549
	18.661	.729	.441	.272	.220	9.013	.234	.687	15.1,6
Stephanodiscus subtilis	2.261	.753	.925	.773	.994	14.709	2.060	2.011	1.474
	31.484	1.331	.883	.666	.611	11.615	3.396	1.955	15.5,6
Stephanodiscus tenuis	.033	.000	.000	.000	.159	.000	.034	.022	.168
	1.082	.000	.000	.000	.379	.000	.127	.067	85.1,2
Surirella angusta	.000								
	.000								
Synedra ostenfeldii	.007	.000	.000	.016	.000	.021	.000	.017	.007
	.191	.000	.000	.055	.000	.042	.000	.051	57.0,2
Ulothrix subconstricta	4.065	2.893	2.497	.773	.867	13.982	6.293	5.340	6.439 **
	41.144	3.101	2.399	1.026	.859	18.222	4.909	2.561	15.3,6
total algal carbon	82.057	75.039	51.014	70.772	78.103	117.365	103.512	82.263	2.670
	235.626	54.192	22.437	34.554	14.668	88.647	36.466	38.792	15.7,6

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Most abundant taxa on tha basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
Staurastrum paradoxum	7.7%	*Staurastrum paradoxum*	8.7%
Glenodinium, Gymnodinium spp.	6.6	*Glenodinium, Gymnodinium* spp.	7.1
flagellate #1	6.1	flagellate #1	6.2
Fragilaria crotonensis	5.0	*Peridinium* spp.	4.6
Peridinium spp.	4.6	*Oocystis* spp.	4.3
Oocystis spp.	4.3	*Fragilaria crotonensis*	4.0

mean total estimated carbon density = 36 μg-C/1

Summary of patterns based on estimated carbon density
(Figs. 19a, 19b, 21a, 41; Table 16)

Regions A and a	high densities of the diatoms *Stephanodiscus subtilis, S. minutus, S. alpinus, Nitzschia bacata, S. tenuis, S. binderanus;* region A consists of one station (#2), which has the highest density of any; all stations in far western corner
Regions B and b	B similar to region a, but with lower density of characteristic taxa and very low density of flagellate #1 and *Stephanodiscus binderanus;* B located at mouth of Niagara near regions A and a; region b has less extreme values and is located in west central part
Regions C and c	high densities of *Glenodinium* spp., *Gymnodinium* spp., *Peridinium* spp., *Oocystis* spp., and *Stephanodiscus binderanus;* consists of scattered clusters of stations
Region D	low densities of most taxa; many stations, most in east

Summary of patterns based on percent estimated carbon
(Figs. 20a, 20b, 21b; Table 17)

Regions A and a	dominated by high percentages of *Stephanodiscus tenuis;* high percentages of *S. minutus;* located in southwest side
Region B	high percentages of *Glenodinium* spp., *Gymnodinium* spp., flagellate #1, *Oocystis* spp., *Peridinium* spp.; three geographically distinct areas scattered over the lake
Regions C and c	all taxa of region B except *Glenodinium* spp. and *Gymnodinium* spp. but in lower percentages; region C has lower percentages of these taxa than region c ; region C in eastern part of lake, region c stations widespread

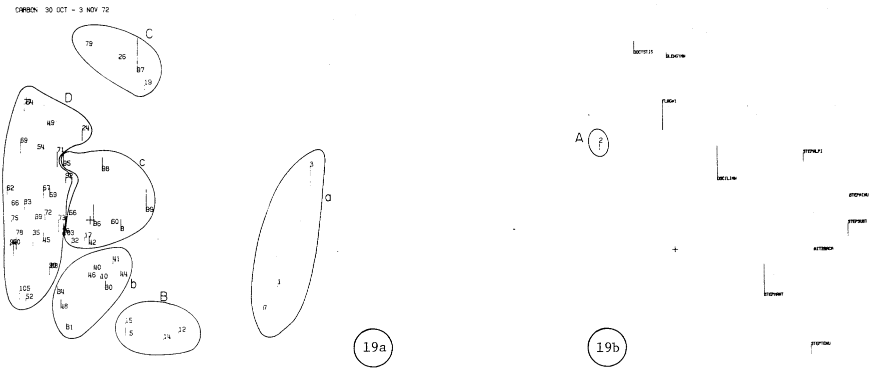


FIG. 19. Ordination of stations and taxa for cruise #5 based on PCA of estimated carbon density. See also Fig. 21a and Table 16. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

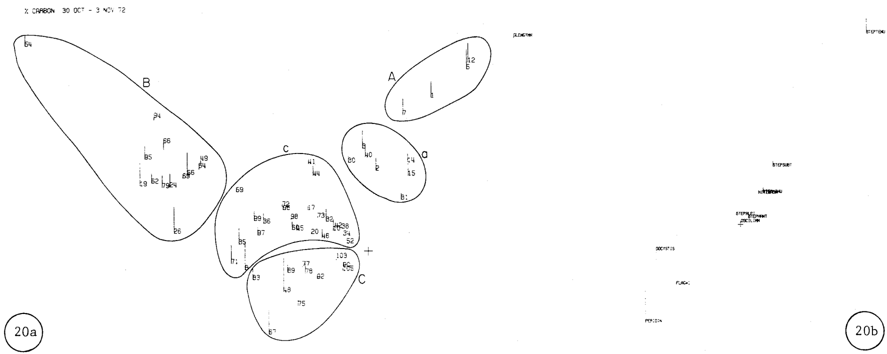
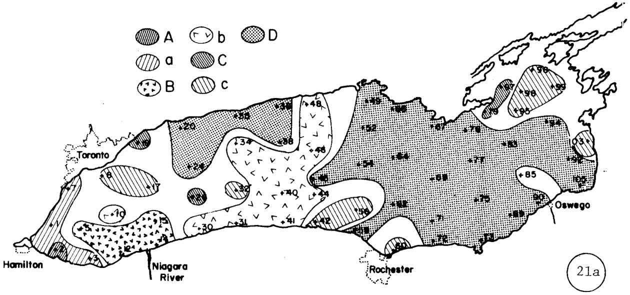


FIG. 20. Ordination of stations and taxa for cruise #5 based on PCA of estimated % carbon density. See also Fig. 21b and Table 17. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings



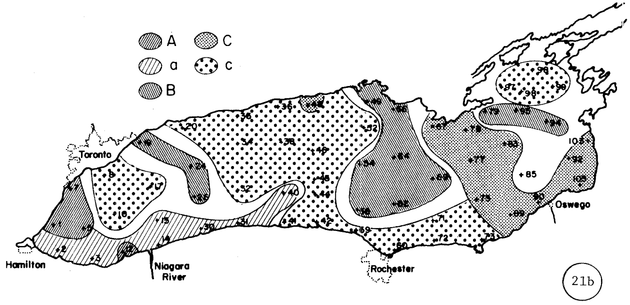


FIG. 21. Geographic location of regions determined by PCA of cruise #5.
(a) regions based on PCA of estimated carbon density. See Fig. 19 and Table 16.
(b) regions based on PCA of estimated % carbon density. See Fig. 20 and Table 17.

TABLE 16. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #5. See Figs. 19, 21a.

30 Oct - 3 Nov 72	Grand 59	A 1	a 3	B 4	b 9	C 4	c 11	D 27	F-stat
Ankistrodesmus falcatus	.033	.000	.026	.026	.017	.032	.026	.044	.991
	.104		.026	.037	.029	.033	.026	.036	9.9,5
Ankistrodesmus setigerus	.000								
	.000								
Asterionella formosa	1.213	.252	1.467	1.163	.545	1.415	2.161	1.034	1.886
	4.402		1.221	1.177	.613	1.968	1.508	1.025	9.5,5
Cryptomonas erosa	.000								
	.000								
Glenodinium, Gymnodinium spp.	2.409	2.409	1.673	.452	1.138	6.526	2.628	2.506	9.249 **
	8.835		.760	.380	.926	2.215	1.622	2.316	11.6,5
Diatoma tenue var. elongatum	.274	.000	.872	.903	.457	.125	.091	.161	1.907
	2.990		.817	1.400	.347	.176	.158	.307	9.5,5
flagellate #1	2.195	3.041	2.618	.876	.560	3.773	1.396	2.948	10.419 **
	8.585		.694	.138	.483	1.833	.632	2.056	11.1,5
flagellate #2	.000								
	.000								
Gloeocystis planctonica	.303	.000	.000	.369	.058	.171	.221	.472	2.553
	2.788		.000	.431	.087	.342	.271	.647	15.3,4
Lagerheimia ciliata	.000								
	.000								
Melosira islandica	.286	3.526	1.091	.189	.084	.000	.000	.317	.547
	5.038		1.293	.378	.178	.000	.000	.999	14.4,3
Nitzschia acicularis	.028	.000	.057	.028	.038	.028	.041	.017	.407
	.397		.057	.033	.075	.057	.119	.035	9.4,5
Nitzschia bacata	.284	2.046	.886	.563	.341	.409	.223	.098	1.535
	2.046		1.009	.563	.422	.373	.434	.164	8.7,5
Nitzschia dissipata	.039	.000	.087	.091	.081	.026	.038	.015	1.714
	.312		.080	.150	.074	.030	.062	.024	8.9,5
Nitzschia sp. #2	.098	.000	.174	.262	.174	.131	.095	.039	.785
	.523		.302	.302	.262	.262	.212	.140	9.0,5
Oocystis spp.	1.559	.996	.456	.031	.346	3.859	1.788	1.899	14.460 **
	5.726		.437	.062	.388	2.105	1.295	1.348	10.9,5
Oscillatoria bornetii	.032	.000	.000	.000	.000	.000	.000	.071	.000
	1.912		.000	.000	.000	.000	.000	.368	0,0
Oscillatoria limnetica	.512	.748	.599	.299	.515	1.085	.653	.382	2.293
	2.245		.150	.212	.238	.859	.234	.358	10.7,5
Phacotus lenticularis	.616	2.960	.846	.317	.235	.529	.538	.721	1.297
	2.960		.423	.405	.564	.532	.630	.535	10.2,5
Peridinium spp.	1.683	1.986	.993	.248	.993	5.710	1.986	1.471	7.194 **
	7.944		.993	.497	1.314	1.696	1.986	1.855	11.3,5
Scenedesmus bicellularis	.144	.162	.234	.148	.168	.162	.113	.136	.208
	.593		.204	.204	.154	.117	.181	.121	9.4,5
S. quadricauda var. quadrispina	.096	.000	.051	.000	.000	.000	.083	.170	.326
	1.832		.088	.000	.000	.000	.197	.391	54.1,2
Staurastrum paradoxum	2.811	2.475	.825	3.713	2.475	1.238	3.600	2.933	1.638
	9.900		1.429	3.195	2.143	1.429	2.563	3.073	10.9,5
Stephanodiscus alpinus	.640	4.193	1.986	.166	.319	1.379	.863	.335	2.008
	5.076		2.685	.331	.400	1.102	.635	.455	9.5,5
Stephanodiscus binderanus	.757	5.742	1.418	.053	.284	.904	1.701	.354	5.783 **
	8.933		.443	.106	.425	1.808	2.687	.624	11.1,5
Stephanodiscus hantzschii	.362	.835	.542	.341	.498	.330	.632	.178	7.104 **
	1.099		.484	.211	.212	.195	.282	.110	8.9,5
Stephanodiscus minutus	.840	6.497	1.980	1.392	.557	1.763	.861	.371	46.151 **
	6.497		.107	.491	.415	.765	.559	.434	12.1,5
Stephanodiscus subtilis	1.375	12.568	4.834	1.078	1.463	1.357	.804	.826	3.014
	12.568		1.877	.431	.765	1.146	.662	.623	9.5,5
Stephanodiscus tenuis	1.065	5.007	6.569	5.775	.718	.242	.352	.138	14.948 **
	8.400		1.712	1.574	.896	.309	.629	.218	8.7,5
Surirella angusta	.217	.854	.664	.071	.127	.427	.259	.148	1.156
	1.423		.435	.142	.207	.678	.348	.365	10.2,5
Synedra ostenfeldii	.006	.000	.000	.020	.018	.000	.000	.003	.388
	.081		.000	.041	.036	.000	.000	.016	27.1,2
Ulothrix subconstricta	1.029	1.102	.477	.165	1.298	1.239	.581	1.277	4.013 *
	3.635		.565	.330	1.415	1.070	.524	.903	10.6,5
total algal carbon	36.272	91.517	47.692	40.506	25.438	49.226	38.081	33.285	6.894
	91.517		9.653	24.193	8.038	5.687	10.277	11.818	10.2,5

TABLE 17. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #5. See Figs. 20, 21b.

30 Oct - 3 Nov 72	Grand 59	A 4	a 7	8 13	C 11	c 24	F-stat
Ankistrodesmus falcatus	.101	.051	.037	.091	.124	.122	1.840
	.441	.074	.065	.098	.114	.121	16.0,4
Ankistrodesmus setigerus	.000						
	.000						
Asterionella formosa	3.343	1.259	2.559	2.527	3.468	4.303	1.965
	12.850	1.459	2.482	3.397	3.517	3.804	18.0,4
Cryptomonas erosa	.000						
	.000						
Glenodinium, Gymnodinium spp.	7.103	2.161	2.680	18.376	1.232	5.802	31.006 **
	35.720	1.101	2.198	5.729	1.494	2.578	17.1,4
Diatoma tenue var. elongatum	.760	1.308	1.663	.742	.213	.667	1.873
	5.899	1.540	1.602	1.622	.588	.829	13.5,4
flagellate #1	6.207	4.957	1.994	8.455	8.734	5.269	6.271 **
	22.372	1.396	2.098	5.124	4.549	4.247	19.3,4
flagellate #2	.000						
	.000						
Gloeocystis planctonica	.820	.631	.375	1.057	1.468	.556	1.503
	5.528	1.262	.647	.987	1.504	1.009	14.6,4
Lagerheimia ciliata	.000						
	.000						
Melosira islandica	.709	2.067	.703	.000	2.034	.260	.889
	12.285	3.274	1.445	.000	3.753	.763	14.1,3
Nitzschia acicularis	.088	.163	.027	.099	.029	.115	1.237
	1.115	.189	.047	.169	.072	.299	15.6,4
Nitzschia bacata	.777	3.999	.589	.341	.316	.742	2.941
	5.586	2.195	.843	.588	.474	1.176	14.0,4
Nitzschia dissipata	.141	.348	.345	.121	.058	.095	.949
	1.395	.576	.515	.197	.081	.160	13.3,4
Nitzschia sp. #2	.297	.861	.409	.000	.343	.310	.253
	2.735	1.022	.729	.000	.852	.640	15.9,3
Oocystis spp.	4.329	.460	.821	7.991	5.756	3.360	16.606 **
	15.834	.641	1.167	3.936	3.769	2.831	21.4,4
Oscillatoria bornetii	.139	.000	.000	.633	.000	.000	.000
	8.239	.000	.000	2.283	.000	.000	0,0
Oscillatoria limnetica	1.551	1.669	1.688	1.315	1.320	1.725	.564
	4.508	.402	1.574	.764	1.387	1.139	17.7,4
Phacotus lenticularis	1.660	.678	1.462	1.741	2.225	1.579	1.533
	5.797	.800	1.282	1.823	1.571	1.498	16.6,4
Peridinium spp.	4.584	.457	1.631	7.023	6.278	4.037	6.624 **
	20.750	.914	1.649	6.009	6.845	4.526	21.9,4
Scenedesmus bicellularis	.474	1.057	.190	.620	.291	.463	1.585
	2.603	1.114	.338	.549	.457	.484	14.2,4
S. quadricauda var. quadrispina	.229	.000	.042	.186	.475	.231	1.388
	2.755	.000	.111	.456	.946	.475	38.4,3
Staurastrum paradoxum	8.701	3.731	14.358	7.614	10.526	7.633	.839
	33.147	7.462	12.189	7.261	11.575	7.282	14.1,4
Stephanodiscus alpinus	1.591	.554	3.044	2.035	1.057	1.345	1.476
	9.741	.858	3.386	2.124	1.505	1.519	16.0,4
Stephanodiscus binderanus	1.892	1.752	1.949	.455	.881	3.141	2.026
	23.197	2.023	2.655	.839	1.301	5.164	13.9,4
Stephanodiscus hantzschii	1.140	1.831	1.483	.830	.901	1.201	1.148
	4.417	1.196	1.690	.544	1.147	.808	13.4,4
Stephanodiscus minutus	2.139	4.617	4.117	1.460	.978	2.049	13.153 **
	7.099	.918	1.639	1.769	.901	1.547	15.5,4
Stephanodiscus subtilis	3.738	6.586	7.143	3.101	2.141	3.347	3.702 *
	13.733	2.249	5.153	2.768	1.837	2.415	14.3,4
Stephanodiscus tenuis	2.842	20.155	7.839	.713	.153	.885	26.525 **
	24.349	4.485	3.197	.787	.509	1.250	13.5,4
Surirella angusta	.562	1.039	.548	.518	.000	.768	.193
	4.019	1.466	.711	1.265	.000	1.046	17.5,3
Synedra ostenfeldii	.023	.123	.040	.000	.000	.025	.160
	.490	.245	.105	.000	.000	.085	18.1,2
Ulothrix subconstricta	3.156	1.901	.711	4.402	2.996	3.477	4.102 *
	11.218	1.902	1.423	3.233	2.159	3.365	16.3,4
total algal carbon	36.272	33.386	46.305	33.167	35.673	35.783	.353
	91.517	16.194	28.319	11.394	14.792	10.520	13.4,4

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Most abundant taxa on the basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
Staurastrum paradoxum	8.6%	*Staurastrum paradoxum*	8.1%
Asterionella formosa	8.3	*Asterionella formosa*	8.1
Peridinium spp.	7.0	*Peridinium* spp.	7.2
Stephanodiscus binderanus	5.7	*Stephanodiscus binderanus*	4.9
Fragilaria crotonensis	4.1	*Stephanodiscus minutus*	3.5
Stephanodiscus hantzschii	2.9	*Stephanodiscus hantzschii*	3.0

mean total estimated carbon density = 26 μg-Cl/l

Summary of patterns based on estimated carbon density (figs. 22a, 22b, 24a, 42; Table 18)

Region A	high densities of *Glenodinium* spp., *Gymnodinium* spp., *Stephanodiscus subtilis, S. hantzschii*, flagellate #1; located mainly in NE
Region D	high densities of *Stephanodiscus alpinus* (also possibly flagellate #2 and *Peridinium* spp.); located mainly in NW
Regions B and C	may be interpreted perhaps as transition regions between regions A and D; region B is more like region A and region C is more like region D; region B is in the eastern half and region C in the western half

Summary of patterns based on percent estimated carbon (Figs. 23a, 23b, 24b; Table 19)

Regions A and a	high percentage of *Peridinium* spp. (higher in region A); located in western half
Regions B and b	high percentages of *Glenodinium* spp., *Gymnodinium* spp., *Phacotus lenticularis* (higher in region B); mainly inshore stations in the south
Region C	mixture of other taxa, none consistently dominant

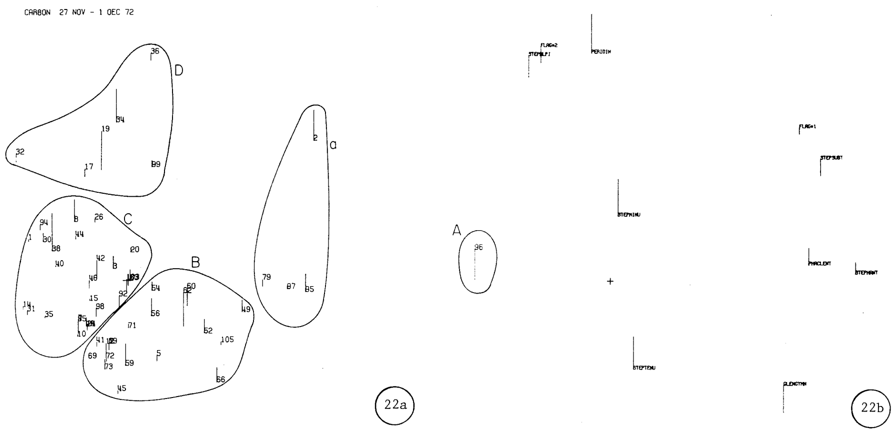

FIG. 22. Ordination of stations and taxa for cruise #6 based on PCA of estimated carbon density. See also Fig. 24a and Table 18. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

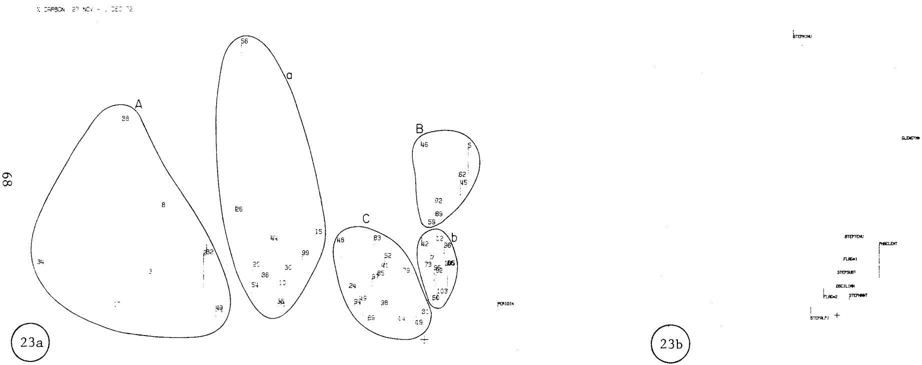

FIG. 23. Ordination of stations and taxa for cruise #6 based on PCA of estimated % carbon density. See also Fig. 24b and Table 19. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

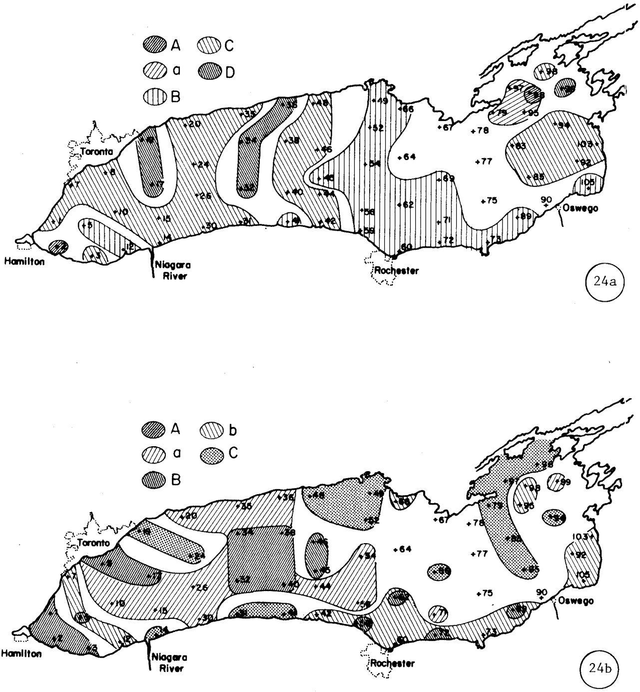

FIG. 24. Geographic location of regions determined by PCA of cruise #6.
(a) regions based on PCA of estimated carbon density. See Fig. 22 and Table 18.
(b) regions based on PCA of estimated % carbon density. See Fig. 23 and Table 19.

TABLE 18. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #6. See Figs. 22, 24a.

27 Nov - 1 Dec 72	Grand 54	A 1	a 4	B 18	C 25	D 6	F-stat
Ankistrodesmus falcatus	.044	.181	.123	.029	.035	.047	6.165 *
	.181		.039	.033	.045	.038	10.5,3
Ankistrodesmus setigerus	.000						
	.000						
Asterionella formosa	2.119	5.408	4.119	1.991	1.705	2.348	1.222
	6.917		2.439	1.927	1.149	2.469	9.2,3
Cryptomonas erosa	.059	.000	.200	.089	.032	.000	.304
	1.601		.400	.377	.160	.000	13.7,2
Glenodinium, Gymnodinium spp.	.547	3.012	.703	.825	.353	.000	3.240
	3.012		.384	.563	.399	.000	16.5,2
Diatoma tenue var. elongatum	.208	.623	.000	.242	.189	.249	.098
	1.619		.000	.388	.262	.453	23.2,2
flagellate #1	.546	1.347	1.001	.490	.411	.840	5.203 *
	1.463		.331	.267	.218	.381	9.6,3
flagellate #2	.351	.264	.154	.073	.430	.999	8.599 **
	1.939		.132	.172	.397	.578	11.6,3
Gloeocystis planctonica	.000						
	.000						
Lagerheimia ciliata	.000						
	.000						
Melosira islandica	.382	1.008	.693	.350	.343	.336	.217
	3.778		.780	.754	.832	.823	10.5,3
Nitzschia acicularis	.018	.000	.028	.032	.011	.000	.760
	.227		.033	.059	.028	.000	15.6,2
Nitzschia bacata	.224	.205	.102	.273	.237	.102	2.172
	1.023		.118	.281	.299	.112	14.6,3
Nitzschia dissipata	.050	.156	.026	.067	.037	.052	.779
	.260		.052	.075	.046	.066	10.1,3
Nitzschia sp. #2	.271	.000	.785	.378	.084	.436	7.757 **
	1.570		.302	.562	.196	.394	9.4,3
Oocystis spp.	.401	1.867	.654	.498	.289	.166	3.288 *
	2.739		.236	.804	.422	.257	13.4,3
Oscillatoria bornetii	.035	.000	.000	.000	.076	.000	.000
	.956		.000	.000	.265	.000	0,0
Oscillatoria limnetica	.435	1.047	.935	.324	.389	.524	2.918
	1.347		.394	.225	.314	.376	9.7,3
Phacotus lenticularis	.728	2.115	2.643	.822	.389	.352	2.151
	5.498		2.111	.978	.645	.494	10.2,3
Peridinium spp.	1.802	.000	2.731	.772	1.907	4.138	3.417
	9.930		3.569	1.207	1.694	3.288	9.3,3
Scenedesmus bicellularis	.112	.108	.067	.126	.101	.144	1.231
	.540		.052	.179	.116	.074	14.3,3
S. quadricauda var. quadrispina	.017	.000	.000	.017	.024	.000	.021
	.611		.000	.072	.122	.000	198.5,1
Staurastrum paradoxum	2.200	4.950	3.094	2.063	1.881	2.888	.313
	9.900		3.713	2.438	2.793	2.433	10.1,3
Stephanodiscus alpinus	.678	.221	.276	.331	.742	1.802	9.963 **
	2.869		.552	.474	.723	.583	10.6,3
Stephanodiscus binderanus	1.347	4.041	5.158	.638	1.344	.496	5.013 *
	8.082		2.402	1.121	1.673	.780	10.9,3
Stephanodiscus hantzschii	.730	1.847	1.572	.806	.508	.674	7.542 **
	2.067		.529	.371	.158	.319	9.0,3
Stephanodiscus minutus	.770	1.114	1.021	.608	.824	.804	1.138
	3.341		.321	.597	.784	.671	12.9,3
Stephanodiscus subtilis	.555	2.528	1.041	.508	.360	.855	3.867 *
	2.528		.598	.303	.245	.428	9.3,3
Stephanodiscus tenuis	.461	.000	.404	.673	.368	.323	2.036
	1.777		.280	.434	.363	.368	11.1,3
Surirella angusta	.485	.285	.712	.427	.501	.474	.366
	1.423		.493	.417	.405	.345	10.4,3
Synedra ostenfeldii	.006	.000	.000	.014	.003	.000	.328
	.163		.000	.042	.016	.000	103.6,1
Ulothrix subconstricta	.479	1.322	.716	.422	.383	.753	.349
	2.203		.941	.446	.618	.961	9.5,3
total algal carbon	25.604	49.795	43.122	22.393	23.528	28.179	27.428
	57.317		3.029	10.191	10.104	6.532	15.8,3

TABLE 19. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #6. See Figs. 23, 24b.

27 Nov - 1 Dec 72	Grand 54	A 9	a 12	B 7	b 11	C 15	F-stat
Ankistrodesmus falcatus	.188	.175	.243	.153	.181	.172	.204
	.759	.140	.249	.241	.231	.195	21.6,4
Ankistrodesmus setigerus	.000						
	.000						
Asterionella formosa	8.108	4.141	9.395	9.122	9.695	7.821	2.972 *
	24.057	2.896	5.851	7.494	6.873	5.465	21.4,4
Cryptomonas erosa	.297	.213	.289	.000	.968	.000	.143
	10.650	.640	1.001	.000	3.211	.000	53.1,2
Glenodinium, Gymnodinium spp.	2.632	.483	1.849	8.317	3.178	1.493	7.884 **
	15.512	.756	2.256	4.369	2.530	1.751	20.7,4
Diatoma tenue var. elongatum	.972	.495	.746	.656	2.086	.768	.680
	10.599	.675	1.306	.877	3.161	1.127	22.4,4
flagellate #1	2.523	2.314	2.584	4.196	2.906	1.537	3.454 *
	7.779	1.185	1.454	2.108	2.639	.913	20.0,4
flagellate #2	1.596	1.865	2.275	1.800	1.030	1.213	.644
	9.712	1.672	3.037	2.541	1.399	1.691	21.1,4
Gloeocystis planctonica	.000						
	.000						
Lagerheimia ciliata	.000						
	.000						
Melosira islandica	1.536	1.456	3.048	.000	1.474	1.137	.226
	20.686	2.396	6.439	.000	1.943	2.587	35.4,3
Nitzschia acicularis	.070	.049	.111	.000	.148	.027	1.189
	.646	.148	.167	.000	.223	.075	30.3,3
Nitzschia bacata	1.044	.842	.784	3.058	.658	.717	1.044
	7.521	.824	1.030	2.964	.671	1.096	20.9,4
Nitzschia dissipata	.236	.069	.218	.642	.174	.206	2.106
	2.316	.105	.357	.844	.174	.199	21.0,4
Nitzschia sp. #2	1.036	1.065	.394	1.330	1.190	1.282	.961
	7.224	1.889	.975	2.713	1.707	1.763	20.3,4
Oocystis spp.	1.684	.893	1.246	1.258	3.338	1.493	1.199
	8.808	1.156	1.902	3.329	3.384	2.029	21.2,4
Oscillatoria bornetii	.153	.000	.458	.000	.000	.186	.074
	5.495	.000	1.586	.000	.000	.721	117.0,1
Oscillatoria limnetica	1.838	1.284	2.360	2.269	1.442	1.843	1.269
	7.014	.735	1.902	1.591	1.320	1.243	21.6,4
Phacotus lenticularis	2.627	2.038	1.486	4.449	4.418	1.729	1.535
	15.044	4.269	2.030	5.193	3.925	2.030	19.6,4
Peridinium spp.	7.175	20.575	12.036	.000	.000	3.856	41.958 **
	30.576	4.840	1.992	.000	.000	1.994	50.5,2
Scenedesmus bicellularis	.577	.390	.987	1.054	.390	.274	1.341
	4.318	.325	1.238	1.541	.365	.295	20.0,4
S. quadricauda var. quadrispina	.083	.270	.000	.000	.185	.000	.017
	2.429	.810	.000	.000	.612	.000	117.3,1
Staurastrum paradoxum	8.142	11.189	4.996	4.009	4.847	13.178	2.066
	34.957	10.193	6.515	7.257	7.034	11.516	21.9,4
Stephanodiscus alpinus	2.810	4.726	2.467	2.409	2.752	2.163	.695
	11.514	4.005	3.050	2.231	2.739	2.714	21.9,4
Stephanodiscus binderanus	4.793	2.874	4.482	1.444	7.405	5.842	2.466
	24.655	4.642	5.595	2.861	5.703	7.589	23.7,4
Stephanodiscus hantzschii	2.989	2.387	2.913	3.396	3.691	2.706	2.945 *
	5.771	.900	1.295	1.350	.829	1.455	21.8,4
Stephanodiscus minutus	3.517	4.835	4.592	5.583	2.223	1.852	2.851
	18.190	5.811	4.593	3.206	1.675	1.856	19.9,4
Stephanodiscus subtilis	2.263	1.733	2.813	2.595	2.046	2.147	.908
	6.663	.918	1.879	1.491	1.432	1.747	22.2,4
Stephanodiscus tenuis	2.177	1.421	2.270	4.068	1.626	2.076	1.213
	7.619	1.304	2.185	3.151	1.779	1.610	21.1,4
Surirella angusta	2.155	1.845	2.083	3.180	2.883	1.387	2.176
	12.109	1.336	1.367	1.104	3.422	1.884	22.7,4
Synedra ostenfeldii	.031	.000	.000	.080	.000	.074	.001
	.610	.000	.000	.212	.000	.196	88.1,1
Ulothrix subconstricta	2.113	2.103	1.916	3.741	1.816	1.733	.334
	10.750	2.863	3.182	4.148	2.568	2.573	20.9,4
total algal carbon	25.604	25.461	22.941	14.563	28.010	31.208	6.722
	57.317	7.410	8.025	4.872	13.181	12.252	23.5,4

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Most abundant taxa on the basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
Stephanodiscus alpinus	13 %	*Stephanodiscus alpinus*	14 %
Stephanodiscus tenuis	10	*Peridinium* spp.	11
Peridinium spp.	9.2	*Stephanodiscus tenuis*	9.2
Asterionella formosa	9.1	*Cryptomonas erosa*	6.9
Cryptomonas erosa	5.7	*Asterionella formosa*	6.7
Stephanodiscus minutus	4.6	*Stephanodiscus hantzschii*	4.8

mean total estimated carbon density = 24 μg-C/1

Summary of patterns based on estimated carbon density
(Figs. 25a, 25b, 27a, 43; Table 20)

Region A	high densities of *Asterionella formosa, Stephanodiscus hantzschii, Glenodinium* spp., *Gymnodinium* spp., and flagellate #1; located in NE corner of lake
Region B	consists of one station in SW corner; high densities of flagellate #2 and *Stephanodiscus subtilis*
Regions C and c	large group of stations with low densities; lowest densities in region C

Summary of patterns based on percent estimated carbon
(Figs. 26a, 26b, 27b; Table 21)

Region A	high percentages of *Asterionella formosa, Stephanodiscus hantzschii, S. tenuis;* located in NE corner
Region B	dominated by high percentage of *Stephanodiscus alpinus;* has high percentage of *Nitzschia bacata;* inshore stations all around the lake
Region C	dominated by *Peridinium* spp. with high percentages of *Nitzschia bacata;* mainly mid-lake stations
Region D	not well characterized; scattered stations

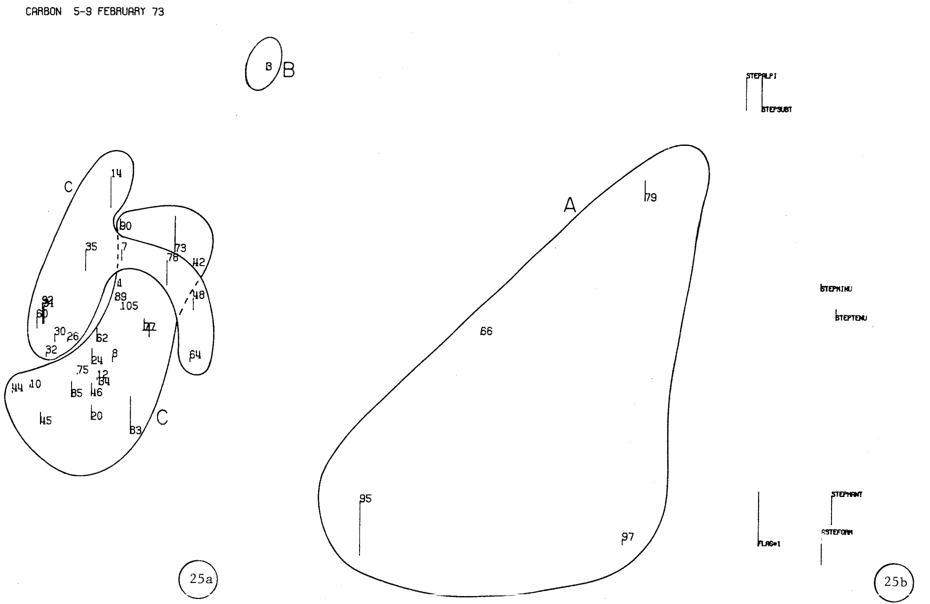

FIG. 25. Ordination of stations and taxa for cruise #7 based on PCA of estimated carbon density. See also Fig. 26a and Table 20. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

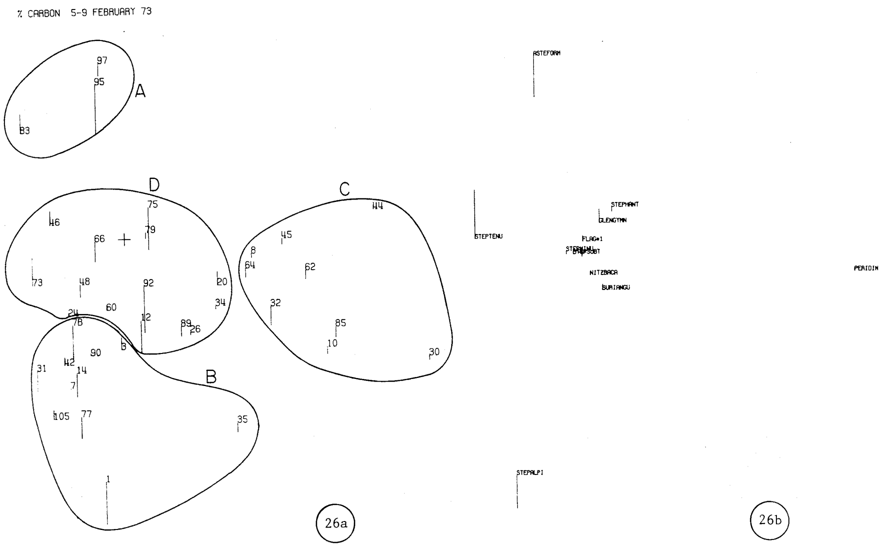

FIG. 26. Ordination of stations and taxa for cruise #7 based on PCA of estimated % carbon density. See also Fig. 26b and Table 21. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

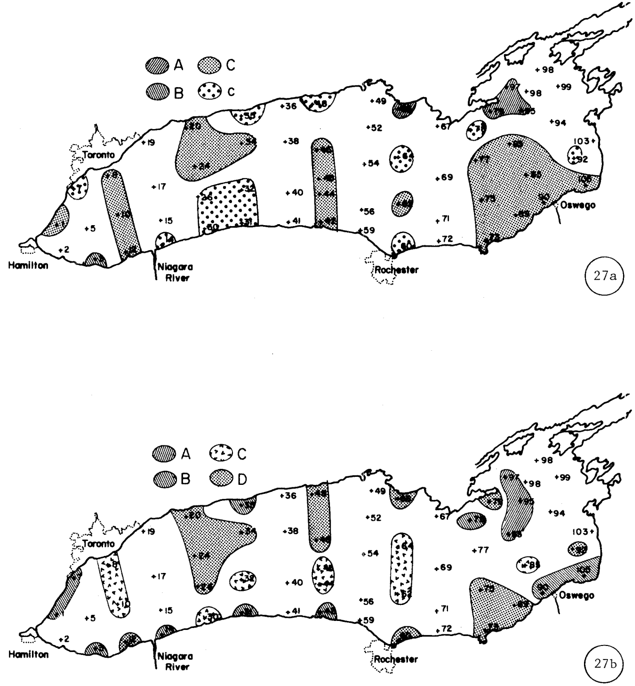

FIG. 27. Geographic location of regions determined by PCA of cruise #7.
(a) regions based on PCA of estimated carbon density. See Fig. 25 and Table 20.
(b) regions based on PCA of estimated % carbon density. See Fig. 26 and Table 21.

TABLE 20. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #7. See Figs. 25, 27a.

5-9 Feb 73	Grand 37	A 4	B 1	C 20	c 12	F-stat	
Ankistrodesmus falcatus	.008 .052	.013 .026	.000	.013 .021	.000 .000	.000 10.3,1	
Ankistrodesmus setigerus	.000 .000						
Asterionella formosa	2.165 19.996	12.796 6.276	.880	.748 .573	1.090 1.189	7.035 6.6,2	*
Cryptomonas erosa	1.342 4.804	1.201 1.533	1.601	1.441 1.437	1.201 1.428	.114 8.3,2	
Glenodinium, Gymnodinium spp.	.499 1.807	1.255 .502	.000	.512 .494	.268 .247	7.396 7.9,2	*
Diatoma tenue var. elongatum	.316 2.865	2.087 1.392	.000	.118 .257	.083 .187	3.812 7.3,2	
flagellate #1	.251 .693	.529 .230	.000	.308 .129	.083 .094	18.735 7.6,2	**
flagellate #2	.067 .705	.044 .088	.705	.066 .134	.022 .055	.820 8.4,2	
Gloeocystis planctonica	.000 .000						
Lagerheimia ciliata	.000 .000						
Melosira islandica	.885 7.053	3.274 2.626	5.289	.239 .379	.798 1.185	3.500 6.5,2	
Nitzschia acicularis	.005 .057	.014 .028	.000	.003 .013	.005 .016	.314 7.2,2	
Nitzschia bacata	.420 1.637	.767 .588	1.023	.307 .270	.443 .312	1.626 7.3,2	
Nitzschia dissipata	.084 .260	.130 .108	.208	.062 .069	.095 .066	1.280 7.7,2	
Nitzschia sp. #2	.453 2.617	.262 .302	.000	.366 .512	.698 .815	1.158 11.4,2	
Oocystis spp.	.111 .996	.124 .249	.000	.131 .317	.083 .194	.144 8.7,2	
Oscillatoria bornetii	.181 5.735	.000 .000	.000	.000 .000	.558 1.654	.000 0,0	
Oscillatoria limnetica	.376 1.047	.524 .356	.449	.314 .265	.424 .291	.929 7.8,2	
Phacotus lenticularis	.229 .846	.106 .211	.000	.233 .321	.282 .275	.842 10.0,2	
Peridinium spp.	2.174 7.944	4.965 2.923	3.972	1.589 1.223	2.069 2.007	2.504 7.0,2	
Scenedesmus bicellularis	.198 .701	.229 .199	.297	.254 .225	.085 .125	3.734 8.3,2	
S. quadricauda var. quadrispina	.008 .305	.000 .000	.305	.000 .000	.000 .000	.000 0,1	
Staurastrum paradoxum	.334 2.475	.619 1.238	.000	.248 .762	.413 .963	.239 7.5,2	
Stephanodiscus alpinus	2.994 7.724	4.966 2.339	5.959	2.097 1.568	3.586 1.835	4.377 7.7,2	
Stephanodiscus binderanus	.609 7.444	4.147 2.704	.638	.117 .271	.248 .433	4.393 6.8,2	
Stephanodiscus hantzschii	1.137 5.365	4.419 .797	.616	.693 .288	.828 .672	38.840 6.8,2	**
Stephanodiscus minutus	1.084 5.012	3.063 1.636	1.485	.733 .513	.974 .747	3.927 7.0,2	
Stephanodiscus subtilis	.129 .892	.335 .386	.818	.108 .186	.037 .067	2.072 7.3,2	
Stephanodiscus tenuis	2.331 13.730	7.390 5.090	6.784	1.583 1.454	1.521 .953	2.410 7.3,2	
Surirella angusta	.854 2.562	1.708 .697	1.992	.712 .550	.712 .613	3.475 7.9,2	
Synedra ostenfeldii	.013 .163	.041 .047	.000	.016 .043	.000 .000	.437 10.8,1	
Ulothrix subconstricta	.164 2.313	.633 .543	.000	.028 .123	.248 .678	2.770 6.4,2	
total algal carbon	23.747 83.115	67.751 13.896	39.639	15.017 5.063	22.335 9.320	27.470 6.9,2	

TABLE 21. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #7. See Figs. 26, 27b.

5-9 Feb 73	Grand 37	A 3	B 11	C 9	D 14	F-stat
Ankistrodesmus falcatus	.048	.000	.021	.077	.060	.533
	.454	.000	.070	.144	.139	32.3,2
Ankistrodesmus setigerus	.000					
	.000					
Asterionella formosa	6.660	22.201	3.592	4.510	7.123	5.467 *
	26.661	7.632	3.472	3.489	5.831	8.2,3
Cryptomonas erosa	6.857	3.157	6.857	10.019	5.616	.837
	22.463	5.468	6.466	8.593	7.188	9.3,3
Glenodinium, Gymnodinium spp.	2.656	3.331	1.340	3.933	2.725	1.465
	11.802	3.315	1.935	3.527	3.047	8.2,3
Diatoma tenue var. elongatum	.970	2.793	.133	.516	1.530	2.766
	8.509	2.476	.306	.696	2.443	7.5,3
flagellate #1	1.460	2.825	.851	1.751	1.459	1.321
	7.285	3.873	.970	1.119	.989	7.8,3
flagellate #2	.324	.000	.459	.335	.280	.145
	2.554	.000	.730	.846	.564	32.2,2
Gloeocystis planctonica	.000					
	.000					
Lagerheimia ciliata	.000					
	.000					
Melosira islandica	3.097	1.971	2.815	5.241	2.180	.407
	24.021	2.349	4.096	8.019	3.537	10.2,3
Nitzschia acicularis	.032	.000	.024	.088	.008	.382
	.794	.000	.079	.265	.029	24.3,2
Nitzschia bacata	2.050	.407	2.699	2.505	1.601	8.582 **
	6.001	.358	1.709	2.014	1.125	15.5,3
Nitzschia dissipata	.407	.127	.333	.453	.495	3.053
	1.834	.111	.214	.415	.544	13.4,3
Nitzschia sp. #2	2.315	2.352	2.458	1.651	2.621	.181
	9.537	3.353	3.300	2.961	2.926	8.6,3
Oocystis spp.	.631	.221	.490	.977	.608	.619
	7.842	.383	1.627	1.587	2.090	16.9,3
Oscillatoria bornetii	.812	.000	2.212	.633	.000	.153
	24.336	.000	7.338	1.899	.000	58.0,1
Oscillatoria limnetica	1.977	3.314	1.747	1.843	1.958	.112
	9.850	4.795	1.583	1.245	1.465	7.9,3
Phacotus lenticularis	1.321	.000	.860	2.149	1.433	.620
	7.752	.000	1.319	3.002	1.565	31.8,2
Peridinium spp.	10.724	4.181	6.241	23.042	7.731	19.541 **
	34.548	4.700	5.157	5.439	5.977	9.1,3
Scenedesmus bicellularis	1.314	.970	.341	2.123	1.633	4.136
	6.149	1.383	.459	1.653	2.049	7.6,3
S. quadricauda var. quadrispina	.021	.000	.070	.000	.000	.000
	.770	.000	.232	.000	.000	0,0
Staurastrum paradoxum	1.608	.000	.509	1.449	2.917	.595
	19.491	.000	1.688	4.347	6.834	29.3,2
Stephanodiscus alpinus	13.595	3.891	21.563	9.206	12.235	31.604 **
	33.498	1.704	4.863	3.791	4.446	12.8,3
Stephanodiscus binderanus	1.398	4.035	.462	.483	2.156	1.905
	8.956	4.221	.835	1.449	2.782	7.7,3
Stephanodiscus hantzschii	4.815	7.275	3.012	5.922	4.994	6.076 *
	12.003	1.390	1.960	2.440	3.063	10.4,3
Stephanodiscus minutus	4.748	5.364	3.904	4.118	5.683	.642
	13.258	4.880	3.765	3.225	3.042	8.2,3
Stephanodiscus subtilis	.501	.686	.730	.131	.521	1.470
	3.549	.942	.961	.392	.965	8.3,3
Stephanodiscus tenuis	9.203	14.685	11.434	4.343	9.528	4.275 *
	22.344	3.754	6.520	3.520	4.964	8.1,3
Surirella angusta	4.041	1.228	4.537	4.178	4.166	4.029 *
	11.941	1.149	3.322	3.579	2.488	12.4,3
Synedra ostenfeldii	.098	.036	.033	.253	.062	.286
	2.274	.063	.109	.758	.193	12.3,3
Ulothrix subconstricta	.580	.890	.977	.296	.385	.396
	10.746	.981	3.240	.887	1.128	9.4,3
total algal carbon	23.747	48.027	23.965	15.399	23.740	2.232
	83.115	35.016	10.221	6.971	20.167	8.0,3

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Most abundant taxa on the basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
Stephanodiscus minutus	18 %	*Stephanodiscus minutus*	17 %
Stephanodiscus tenuis	14	*Stephanodiscus tenuis*	11
Asterionella formosa	10	*Stephanodiscus alpinus*	9.9
Stephanodiscus alpinus	8.1	*Peridinium* spp.	9.6
Peridinium spp.	7.3	*Asterionella formosa*	8.6
Stephanodiscus hantzschii	5.9	*Stephanodiscus subtilis*	6.4

mean total estimated carbon density = 60 μg-C/l

Summary of patterns based on estimated carbon density
(Figs. 28a, 28b, 30a, 44; Table 22)

Region A — high densities of *Stephanodiscus minutus, Asterionella formosa, S. hantzschii, Nitzschia bacata, Glenodinium* spp., and *Gymnodinium* spp.; highest total density of any region; located in NE

Region B — high densities of diatoms of region A (but with lower densities that region A) and low densities of *Glenodinium* spp., *Gymnodinium* spp., flagellate #1; located at inshore stations along southern shore

Region C — high densities of *Scenedesmus bicellularis,* low total density; midlake stations, especially in west

Region D — low total density; scattered stations

Summary of patterns based on percent estimated carbon
(Figs. 29a, 29b, 30b; Table 23)

Regions A and a — dominated by high percentages of *Stephanodiscus subtilis* and *S. minutus,* the former more abundant in region A, the latter in region a; located inshore, especially in SE

Regions B and b — dominated by *Stephanodiscus tenuis;* region B represented by only one station (#60) near Rochester; region b stations generally inshore in south

Regions C and c — high percentages of *Peridinium* spp. and *Stephanodiscus alpinus;* the former more abundant in region C, the latter in region c; offshore stations with some inshore in west

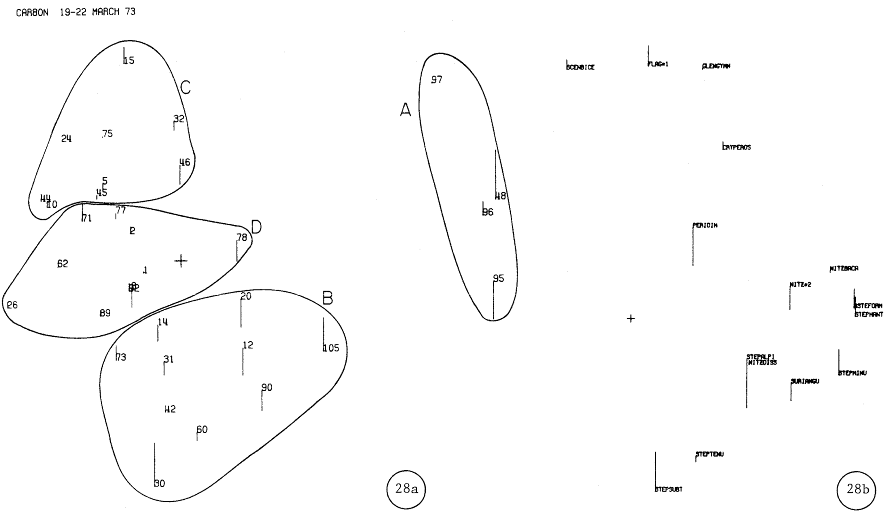


FIG. 28. Ordination of stations and taxa for cruise #8 based on PCA of estimated carbon density. See also Fig. 30a and Table 22. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

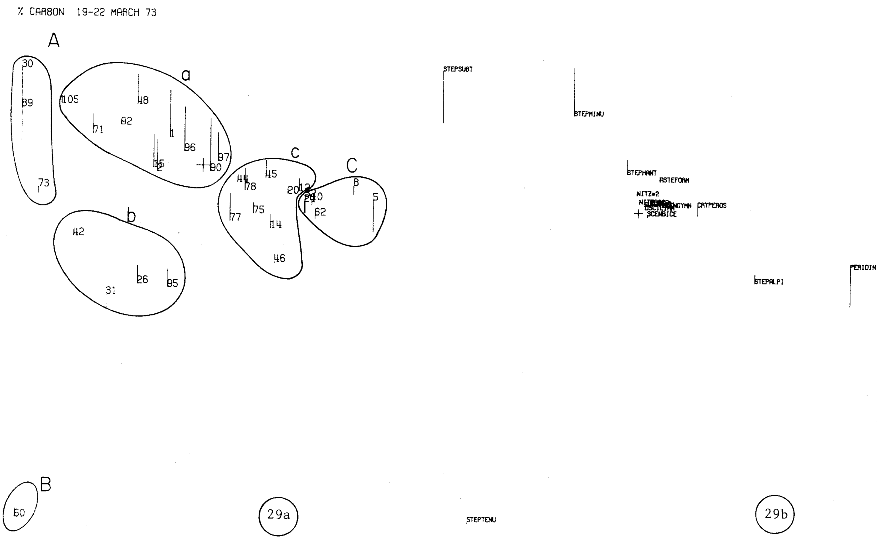
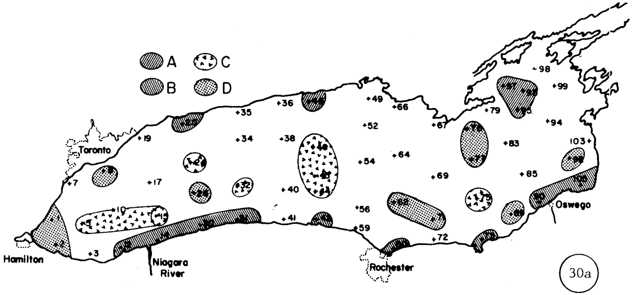


FIG. 29. Ordination of stations and taxa for cruise #8 based on PCA of estimated % carbon density. See also Fig. 30b and Table 23. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings



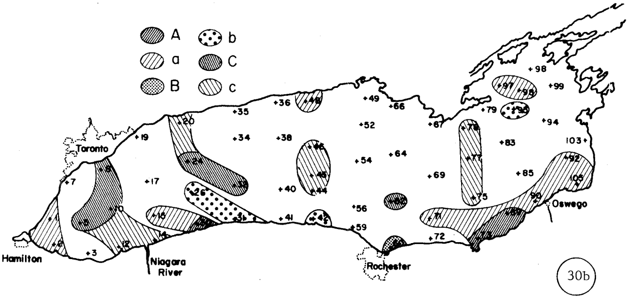


FIG. 30. Geographic location of regions determined by PCA of cruise #8.
(a) regions based on PCA of estimated carbon density. See Fig. 28 and Table 22.
(b) regions based on PCA of estimated % carbon density. See Fig. 29 and Table 23.

TABLE 22. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #8. See Figs. 28, 30a

19-22 Mar 73	Grand 33	A 4	B 10	C 9	D 10	F-stat
Ankistrodesmus falcatus	.013	.026	.008	.009	.016	.894
	.078	.021	.013	.018	.028	10.8,3
Ankistrodesmus setigerus	.000					
	.000					
Asterionella formosa	6.056	22.480	5.898	2.627	2.729	16.622 **
	30.183	5.400	3.945	1.855	2.259	10.4,3
Cryptomonas erosa	2.135	4.204	1.281	2.580	1.761	2.996
	8.007	2.002	.774	2.428	1.054	10.2,3
Glenodinium, Gymnodinium spp.	1.107	2.259	.321	1.584	1.004	9.314 **
	3.413	.842	.393	.976	.852	10.3,3
Diatoma tenue var. elongatum	.174	.685	.174	.028	.100	3.224
	1.370	.461	.428	.055	.141	9.6,3
flagellate #1	.735	1.020	.246	1.095	.785	8.508 **
	2.387	.605	.278	.532	.329	10.4,3
flagellate #2	.136	.352	.079	.059	.176	.586
	1.410	.705	.222	.117	.291	10.0,3
Gloeocystis planctonica	.003	.000	.000	.000	.011	.000
	.109	.000	.000	.000	.035	0,0
Lagerheimia ciliata	.002	.000	.000	.009	.000	.000
	.079	.000	.000	.026	.000	0,0
Melosira islandica	2.542	8.753	2.569	.896	1.511	4.424 *
	14.105	5.176	1.618	1.084	1.866	10.3,3
Nitzschia acicularis	.003	.000	.011	.000	.000	.000
	.113	.000	.036	.000	.000	0,0
Nitzschia bacata	.800	2.557	.696	.477	.491	7.037 **
	3.682	.827	.564	.579	.388	10.6,3
Nitzschia dissipata	.188	.299	.229	.168	.120	2.933
	.573	.214	.118	.124	.049	9.7,3
Nitzschia sp. #2	1.364	2.879	1.309	.931	1.204	1.013
	5.758	2.282	.932	.730	1.048	10.5,3
Oocystis spp.	.015	.124	.000	.000	.000	.000
	.498	.249	.000	.000	.000	0,0
Oscillatoria bornetii	.029	.000	.096	.000	.000	.000
	.956	.000	.302	.000	.000	0,0
Oscillatoria limnetica	.390	.786	.254	.515	.254	2.527
	1.197	.430	.283	.382	.212	10.5,3
Phacotus lenticularis	.243	.000	.634	.094	.085	2.000
	1.692	.000	.669	.186	.267	29.8,2
Peridinium spp.	4.333	6.703	3.674	5.958	2.582	1.389
	12.909	4.684	3.312	4.213	3.894	11.1,3
Scenedesmus bicellularis	.360	.337	.086	.824	.224	32.031 **
	1.106	.219	.112	.185	.177	10.6,3
S. quadricauda var. quadrispina	.000					
	.000					
Staurastrum paradoxum	.825	.619	1.733	.275	.495	.859
	7.425	1.238	2.622	.825	1.044	11.1,3
Stephanodiscus alpinus	4.748	7.559	5.893	3.629	3.487	1.047
	17.435	7.361	4.156	2.339	3.242	10.4,3
Stephanodiscus binderanus	.470	2.499	.234	.165	.170	.690
	7.019	3.213	.255	.365	.411	10.1,3
Stephanodiscus hantzschii	3.482	15.303	4.041	.537	.844	14.763 **
	19.128	4.498	4.369	.325	.666	9.7,3
Stephanodiscus minutus	10.468	26.961	13.234	4.475	6.497	9.272 **
	37.123	9.193	7.991	2.857	3.311	10.3,3
Stephanodiscus subtilis	4.478	3.737	10.738	.471	2.119	2.433
	49.081	6.005	15.707	.518	2.955	9.2,3
Stephanodiscus tenuis	8.233	14.295	16.638	2.369	2.681	2.190
	84.480	11.469	24.634	2.247	1.261	9.6,3
Surirella angusta	1.354	1.921	1.793	.822	1.167	8.100 **
	3.700	.358	.996	.414	.677	13.1,3
Synedra ostenfeldii	.037	.020	.073	.018	.024	1.340
	.163	.041	.071	.054	.055	12.8,3
Ulothrix subconstricta	.170	.083	.165	.086	.286	.350
	1.983	.165	.357	.257	.657	14.4,3
total algal carbon	58.958	135.224	77.809	32.713	33.221	100.970
	141.559	9.571	36.411	11.423	14.621	13.0,3

TABLE 23. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #8. See Figs. 29, 30b.

19-22 Mar 73	Grand 33	A 3	a 10	B 1	b 4	C 6	c 9	F-stat
Ankistrodesmus falcatus	.029	.007	.063	.000	.005	.000	.030	1.331
	.261	.012	.081		.009	.000	.071	15.9,3
Ankistrodesmus setigerus	.000							
	.000							
Asterionella formosa	8.551	6.470	9.366	4.548	8.236	8.303	9.090	.208
	21.357	4.744	6.214		3.259	4.482	3.376	8.8,4
Cryptomonas erosa	4.893	1.257	4.049	.579	3.120	11.785	3.715	3.432
	19.155	1.664	2.286		3.231	6.228	2.391	9.0,4
Glenodinium, Gymnodinium spp.	2.717	.417	2.692	.000	.520	2.772	4.754	5.282 *
	13.129	.428	2.542		.695	2.115	3.611	12.2,4
Diatoma tenue var. elongatum	.252	.354	.414	.000	.251	.000	.236	.151
	1.959	.613	.631		.501	.000	.265	9.7,3
flagellate #1	1.976	1.140	2.129	.223	.911	3.421	1.788	1.506
	6.100	1.720	1.869		1.175	1.904	1.438	8.9,4
flagellate #2	.267	.125	.659	.000	.000	.000	.205	.775
	2.373	.217	.842		.000	.000	.421	30.7,2
Gloeocystis planctonica	.005	.000	.000	.000	.000	.000	.019	.000
	.171	.000	.000		.000	.000	.057	0,0
Lagerheimia ciliata	.010	.000	.000	.000	.000	.000	.036	.000
	.324	.000	.000		.000	.000	.108	0,0
Melosira islandica	3.720	.197	6.662	2.368	2.184	3.234	2.782	7.630 *
	14.400	.341	4.315		2.282	2.614	3.173	10.9,4
Nitzschia acicularis	.003	.000	.010	.000	.000	.000	.000	.000
	.100	.000	.032		.000	.000	.000	0,0
Nitzschia bacata	1.448	1.966	1.772	.296	.740	1.443	1.362	.792
	4.396	1.786	.862		.935	1.663	1.397	8.3,4
Nitzschia dissipata	.427	.351	.352	.226	.307	.495	.568	.561
	1.490	.295	.173		.158	.506	.457	8.6,4
Nitzschia sp. #2	2.637	2.976	3.064	.379	2.140	1.558	3.240	.781
	8.928	5.154	2.055		1.729	1.733	2.029	8.4,4
Oocystis spp.	.012	.000	.041	.000	.000	.000	.000	.000
	.411	.000	.130		.000	.000	.000	0,0
Oscillatoria bornetii	.057	.626	.000	.000	.000	.000	.000	.000
	1.877	1.084	.000		.000	.000	.000	0,0
Oscillatoria limnetica	.852	.137	.901	.000	.382	.877	1.325	4.560 *
	3.490	.148	.895		.343	.673	1.048	11.9,4
Phacotus lenticularis	.438	.000	.353	.918	.162	.667	.594	.496
	3.029	.000	.806		.323	1.086	1.045	20.3,3
Peridinium spp.	9.604	.000	2.679	5.027	3.349	24.145	14.395	14.836 **
	37.133	.000	3.401		3.934	7.654	5.116	15.8,3
Scenedesmus bicellularis	1.145	.584	.636	.039	1.264	1.815	1.520	1.456
	4.773	.714	.886		2.340	1.065	1.671	9.0,4
S. quadricauda var. quadrispina	.000							
	.000							
Staurastrum paradoxum	1.313	3.553	1.254	.000	1.537	.000	1.554	.286
	10.115	3.113	2.636		3.075	.000	3.456	10.8,3
Stephanodiscus alpinus	9.913	1.575	4.862	3.990	11.578	12.555	16.460	22.482 **
	25.294	1.084	5.147		3.624	4.258	5.193	11.3,4
Stephanodiscus binderanus	.568	.445	1.119	.308	1.283	.000	.089	1.508
	5.132	.420	1.428		2.566	.000	.266	9.6,3
Stephanodiscus hantzschii	4.317	3.979	6.980	1.972	3.088	2.586	3.432	1.011
	13.535	1.959	6.153		2.791	1.787	2.045	9.1,4
Stephanodiscus minutus	16.947	16.598	24.776	11.411	13.611	9.843	15.200	18.944 **
	30.777	2.074	3.760		2.598	2.638	4.894	10.0,4
Stephanodiscus subtilis	6.363	31.610	7.049	1.345	8.312	.308	.914	10.073 **
	38.343	8.833	7.810		6.613	.753	1.280	7.9,4
Stephanodiscus tenuis	11.258	13.612	8.110	61.099	24.546	3.551	7.665	41.882 **
	61.099	6.481	2.106		2.585	1.679	4.038	8.2,4
Surirella angusti	2.844	2.992	2.444	.412	3.018	2.304	3.793	.879
	7.918	2.778	.951		1.829	.617	2.123	8.0,4
Synedra ostenfeldii	.065	.053	.020	.059	.062	.111	.091	.698
	.468	.092	.047		.124	.192	.146	7.6,4
Ulothrix subconstricta	.446	.000	.507	.478	.060	1.132	.236	.692
	5.070	.000	1.603		.121	1.915	.797	10.1,3
total algal carbon	58.958	67.464	76.498	138.266	73.221	30.532	40.434	2.418
	141.559	54.202	47.607		52.039	11.412	13.392	7.9,4

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Most abundant taxa on the basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
Stephanodiscus minutus	23 %	*Stephanodiscus minutus*	25 %
Stephanodiscus tenuis	20	*Stephanodiscus tenuis*	16
Asterionella formosa	14	*Asterionella formosa*	14
Peridinium spp.	9.3	*Peridinium* spp.	9.0
Melosira islandica	8.5	*Melosira islandica*	8.8
Nitzschia sp. #2	3.4	*Nitzschia* sp. #2	3.7

mean total estimated carbon density = 136 μg-C/1

Summary of patterns based on estimated carbon density
(Figs. 31a, 31b, 33a, 45; Table 24)

Regions A and a — high densities of *Stephanodiscus minutus, Asterionella formosa, Melosira islandica, Nitzschia bacata, S. hantzschii, Glenodinium* spp., and *Gymnodinium* spp.; mainly inshore stations in north

Regions B and b — high densities of *Stephanodiscus tenuis, Peridinium* spp., *Cryptomonas erosa,* flagellate #1, *Scenedesmus bicellularis, Diatoma tenue* var. *elongatum;* located in NE

Region C — no clearly defined community; tendancy for high densities of *Surirella angusta, Stephanodiscus alpinus, Nitzschia dissipata* but without statistical significance; stations generally inshore in west

Regions D and d — low densities; region D in mid-lake, region d in SE

Summary of patterns based on percent estimated carbon
(Figs. 32a, 32b, 33b ; Table 25)

Region A — high percentage of *Asterionella formosa,* low of flagellate #1; mainly inshore stations of SW

Region B — dominated by *Stephanodiscus minutus,* high in *Nitzschia bacata* and *Scenedesmus bicellularis;* mid-lake stations

Region AB — characteristics of both regions A and B but less marked; mainly located in NW part centered around station #34

Region C — high percentage of *Stephanodiscus tenuis;* mainly mid-lake stations

Region BC — characteristics of both regions B and C but less marked; located in east

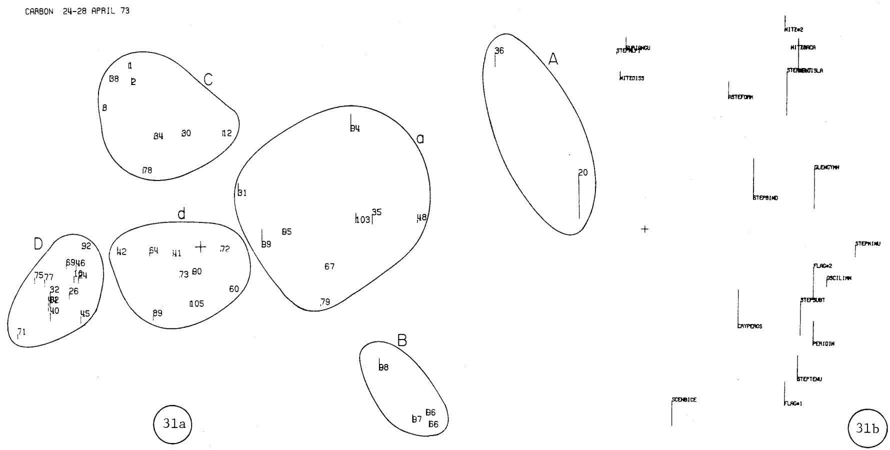


FIG. 31. Ordination of stations and taxa for cruise #9 based on PCA of estimated carbon density. See also Fig. 33a and Table 24. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

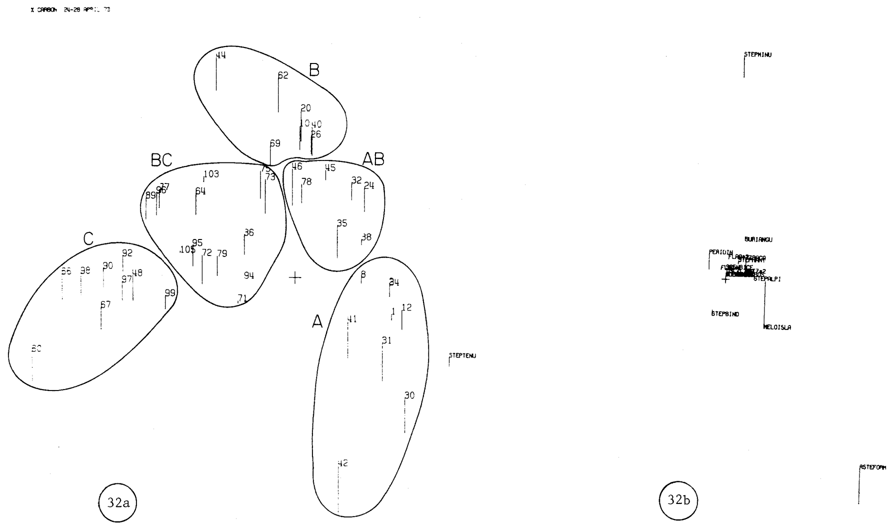
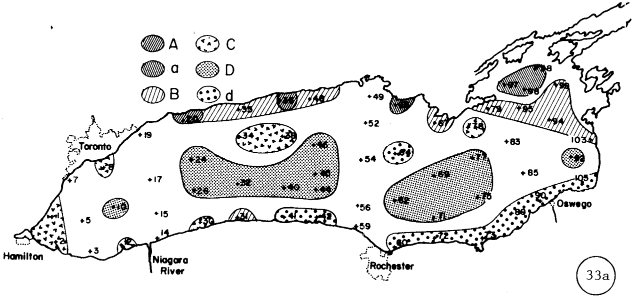


FIG. 32. Ordination of stations and taxa for cruise #9 based on PCA of estimated % carbon density. See also Fig. 33b and Table 25. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings



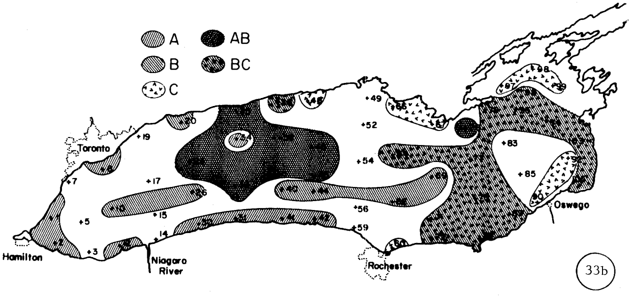


FIG. 33. Geographic location of regions determined by PCA of cruise #9.
(a) regions based on PCA of estimated carbon density. See Fig. 31 and Table 24.
(b) regions based on PCA of estimated % carbon density. See Fig. 32 and Table 25.

TABLE 24. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #9. See Figs. 31, 33a.

24-28 Apr 73	Grand 46	A 2	a 9	B 4	C 8	D 14	d 9	F-stat
Ankistrodesmus falcatus	.037	.065	.055	.091	.016	.026	.023	1.554
	.155	.055	.040	.054	.046	.030	.033	7.4,5
Ankistrodesmus setigerus	.000							
	.000							
Asterionella formosa	18.744	30.560	27.807	16.632	26.457	3.566	24.747	26.166 **
	71.810	6.225	18.509	2.172	15.696	1.988	21.796	7.3,5
Cryptomonas erosa	3.551	.400	5.427	7.006	3.603	1.430	4.092	9.223 **
	9.608	.566	2.767	2.878	2.383	1.183	1.979	9.9,5
Glenodinium, Gymnodinium spp.	.428	3.012	.580	.803	.151	.129	.245	32.338 **
	3.213	.284	.496	.284	.142	.169	.297	7.5,5
Diatoma tenue var. elongatum	.663	.685	1.924	.062	.483	.044	.789	4.048 *
	7.972	.264	2.819	.072	.640	.079	.758	7.5,5
flagellate #1	1.279	1.251	1.762	4.283	.505	.630	1.163	9.267 **
	5.659	.844	1.106	1.023	.388	.256	.893	7.1,5
flagellate #2	1.835	5.816	2.781	3.150	1.102	.906	1.518	3.419
	7.931	2.991	1.413	2.657	1.070	.549	.846	7.1,5
Gloeocystis planctonica	.014	.000	.036	.000	.041	.000	.000	.001
	.328	.000	.109	.000	.116	.000	.000	169.3,1
Lagerheimia ciliata	.000							
	.000							
Meolsira islandica	11.493	19.772	17.911	17.191	16.876	2.537	9.851	19.267 **
	32.240	10.152	6.132	5.031	6.292	1.904	3.983	7.1,5
Nitzschia acicularis	.014	.000	.013	.000	.014	.020	.013	.088
	.113	.000	.025	.000	.026	.036	.025	44.4,3
Nitzschia bacata	2.793	5.728	4.251	2.455	3.554	1.432	2.273	19.835 **
	6.137	.579	1.101	1.357	1.048	.642	1.005	8.0,5
Nitzschia dissipata	.239	.260	.249	.156	.443	.223	.104	2.219
	.989	.074	.137	.128	.296	.164	.119	9.0,5
Nitzschia sp. #2	4.620	12.563	7.794	4.057	6.085	1.570	3.373	9.314 **
	18.845	2.961	4.969	1.676	2.438	1.179	2.063	7.4,5
Oocystis spp.	.114	.000	.000	.000	.654	.000	.000	.000
	5.228	.000	.000	.000	1.848	.000	.000	0,0
Oscillatoria bornetii	.145	.000	.212	1.195	.000	.000	.000	.209
	3.823	.000	.637	1.809	.000	.000	.000	38.9,1
Oscillatoria limnetica	.865	1.796	1.397	1.833	.711	.460	.466	26.230 **
	2.394	.423	.652	.188	.398	.350	.204	7.9,5
Phacotus lenticularis	.092	.000	.047	.000	.159	.121	.094	.325
	1.269	.000	.141	.000	.219	.349	.186	44.1,3
Peridinium spp.	12.585	18.371	18.205	39.472	6.330	3.972	12.688	45.041 **
	44.685	6.319	7.579	4.084	3.898	2.237	9.179	7.2,5
Scenedesmus bicellularis	.327	.499	.378	.526	.074	.430	.216	9.360 **
	1.214	.553	.379	.276	.057	.170	.264	7.2,5
S. quadricauda var. quadrispina	.000							
	.000							
Staurastrum paradoxum	.054	.000	.275	.000	.000	.000	.000	0.000
	2.475	.000	.825	.000	.000	.000	.000	0,0
Stephanodiscus alpinus	1.156	1.655	.049	.000	4.552	.772	.245	1.911
	13.021	2.341	.147	.000	4.445	1.805	.499	8.8,4
Stephanodiscus binderanus	4.443	5.317	14.391	8.295	.744	.000	2.788	2.894
	43.813	5.715	12.577	5.881	1.469	.000	3.305	7.8,4
Stephanodiscus hantzschii	2.312	10.290	3.371	1.033	2.320	1.168	1.822	317.561 **
	10.466	.249	2.319	.369	1.079	.489	.928	9.9,5
Stephanodiscus minutus	31.268	83.620	45.146	60.186	21.740	12.317	30.853	21.826 **
	97.077	19.031	9.374	20.445	6.449	4.886	9.431	7.2,5
Stephanodiscus subtilis	.500	2.454	.421	1.450	.084	.117	.686	4.837 *
	3.941	2.103	.370	.827	.184	.151	.419	7.1,5
Stephanodiscus tenuis	27.397	32.719	44.277	90.779	4.442	4.742	36.811	37.068 **
	108.063	19.303	27.350	11.388	3.137	5.521	29.388	7.2,5
Surirella angusta	2.593	2.419	2.498	1.637	4.518	1.911	2.498	1.873
	8.254	.201	1.082	1.302	2.374	.976	1.414	13.5,5
Synedra ostenfeldii	.065	.000	.090	.163	.029	.076	.036	1.806
	.329	.009	.086	.148	.038	.087	.082	19.7,4
Ulothrix subconstricta	.199	.275	.343	.413	.317	.000	.147	.427
	.771	.389	.328	.364	.346	.000	.291	8.4,4
total algal carbon	135.566	252.960	211.237	279.814	110.300	39.008	142.361	91.455
	315.678	34.744	28.913	28.150	24.974	12.115	41.430	7.2,5

TABLE 25. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #9. See Figs. 32, 33b.

24-28 Apr 73	Grand 46	A 9	B 7	AB 7	C 9	BC 14	F-stat
Ankistrodesmus falcatus	.037	.023	.087	.012	.022	.044	2.016
	.247	.049	.070	.022	.019	.069	18.2,4
Ankistrodesmus setigerus	.000						
	.000						
Asterionella formosa	13.564	28.765	7.234	15.406	8.801	9.098	14.614 **
	44.546	8.500	2.528	4.472	2.416	5.025	18.5,4
Cryptomonas erosa	3.136	3.128	3.093	4.025	2.442	3.165	.493
	9.083	2.480	2.704	3.013	1.440	2.209	17.6,4
Glenodinium, Gymnodinium spp.	.300	.134	.308	.481	.206	.374	1.768
	1.407	.164	.559	.471	.183	.331	17.4,4
Diatoma tenue var. elongatum	.425	.777	.094	.253	.243	.567	1.363
	4.642	.831	.163	.273	.473	1.211	19.2,4
flagellate #1	1.101	.457	1.465	1.132	1.091	1.323	6.987 **
	2.951	.316	.500	.559	.696	.936	18.3,4
flagellate #2	1.651	.970	3.000	2.123	1.081	1.544	2.472
	5.168	.959	1.809	1.432	.779	.783	16.9,4
Gloeocystis planctonica	.007	.023	.000	.000	.015	.000	.024
	.208	.069	.000	.000	.044	.000	108.1,1
Lagerheimia ciliata	.000						
	.000						
Melosira islandica	8.802	12.701	4.316	9.400	6.789	9.534	4.198 *
	23.968	7.603	2.588	3.894	2.095	5.240	18.4,4
Nitzschia acicularis	.021	.007	.083	.030	.006	.005	1.098 **
	.247	.021	.107	.057	.012	.014	16.3,4
Nitzschia bacata	2.672	2.342	3.382	3.804	1.365	2.803	8.406
	6.325	1.123	1.480	1.490	.430	1.577	16.8,4
Nitzschia dissipata	.303	.326	.399	.409	.166	.276	1.167
	1.325	.381	.202	.384	.239	.428	18.9,4
Nitzschia sp. #2	3.723	3.807	3.052	6.063	2.459	3.647	1.929
	12.239	1.870	2.443	3.556	1.376	2.400	17.7,4
Oocystis spp.	.127	.000	.000	.832	.000	.000	.000
	5.821	.000	.000	2.200	.000	.000	0,0
Oscillatoria bornetii	.054	.000	.000	.000	.037	.153	.266
	1.211	.000	.000	.000	.112	.393	128.6,1
Oscillatoria limnetica	.767	.575	1.021	1.175	.638	.643	1.049
	2.767	.451	1.052	.734	.250	.336	16.7,4
Phacotus lenticularis	.123	.130	.513	.055	.054	.000	.521
	2.805	.205	1.052	.146	.109	.000	21.7,3
Peridinium spp.	8.957	7.788	11.717	7.566	10.132	8.269	.795
	23.421	4.865	7.240	3.610	4.011	3.774	17.7,4
Scenedesmus bicellularis	.494	.038	1.130	.662	.149	.607	8.961 **
	2.307	.050	.719	.535	.109	.704	16.1,4
S. quadricauda var. quadrispina	.000						
	.000						
Staurastrum paradoxum	.026	.000	.000	.000	.000	.086	.000
	1.208	.000	.000	.000	.000	.323	0,0
Stephanodiscus alpinus	1.256	3.650	3.215	.284	.011	.023	3.224 *
	12.301	3.650	4.539	.542	.032	.058	15.8,4
Stephanodiscus binderanus	2.145	2.111	.080	1.055	3.319	2.991	4.091 *
	19.550	3.443	.211	1.567	3.348	5.123	16.5,4
Stephanodiscus hantzschii	2.070	2.074	3.269	2.875	1.186	1.634	4.196 *
	5.315	1.201	1.302	1.486	.793	1.258	17.3,4
Stephanodiscus minutus	25.000	16.921	37.234	29.617	19.039	25.600	19.278 **
	46.266	3.731	6.840	4.863	2.871	4.878	17.8,4
Stephanodiscus subtilis	.336	.167	.419	.275	.352	.424	1.174
	1.726	.283	.680	.400	.275	.287	17.3,4
Stephanodiscus tenuis	16.304	5.336	8.436	5.644	35.144	20.509	47.248 **
	47.645	4.643	4.622	3.944	6.044	4.737	18.4,4
Surirella angusta	3.106	2.839	4.888	4.619	1.395	2.731	3.137 *
	11.685	2.558	3.713	2.627	1.298	2.647	17.5,4
Synedra ostenfeldii	.082	.027	.085	.167	.081	.073	1.172
	.780	.041	.108	.286	.112	.170	16.7,4
Ulothrix subconstricta	.122	.191	.000	.160	.129	.117	.115
	.875	.315	.000	.274	.136	.177	25.5,3
total algal carbon	135.566	133.703	68.457	77.404	218.100	146.344	5.846
	3?5.678	39.039	70.891	58.761	69.254	91.591	18.3,4

CRUISE 10 11-14 JUNE 1973

Most abundant taxa on the basis of estimated carbon density		Most abundant taxa on the basis of estimated percent carbon	
flagellate #1	22 %	*Stephanodiscus minutus*	21 %
Stephanodiscus minutus	21	flagellate #1	21
Peridinium spp.	10	*Peridinium* spp.	10
Oscillatoria limnetica	7.2	*Oscillatoria limnetica*	7.4
Stephanodiscus binderanus	6.5	*Stephanodiscus binderanus*	6.1
Stephanodiscus tenuis	5.0	*Asterionella formosa*	4.7

mean total estimated carbon density = 124 μg-C/l

Summary of patterns based on estimated carbon density
(Figs. 34a, 34b, 36a, 45; Table 26)

Regions A and a	high densities of *Stephanodiscus minutus, S. tenuis, S. subtilis, S. hantzschii;* very high total density; region A located off Toronto; region a mainly in NW
Region B	high densities of *Peridinium* spp. and flagellate #2; scattered stations, mainly in east
Region C	tendancy for high densities of *Nitzschia acicularis, Ankistrodesmus falcatus, Scenedesmus bicellularis, Glenodinium* spp., and *Gymnodinium* spp. but without statistical significance; located in SW
Region D	low densities; located in south and east

Summary of patterns based on percent estimated carbon
(Figs. 35a, 35b, 36b; Table 27)

Region A	dominated by high percentage of *Stephanodiscus minutus;* low percentage of flagellate #2; located in north-central part
Regions B and b	high percentage of *Stephanodiscus binderanus;* scattered inshore stations
Region C	high percentage of flagellate #1; scattered areas in south and east
Region AB	characteristics of regions A and B; tendancy for high percentages of *Stephanodiscus tenuis;* located near stations of region B
Region AC	characteristics of regions A and C; located mainly in north-central part
Region BC	characteristics of regions B and C; located mainly along southern shore
Region D	high percentage of *Peridinium* spp.; located mainly in central lake area

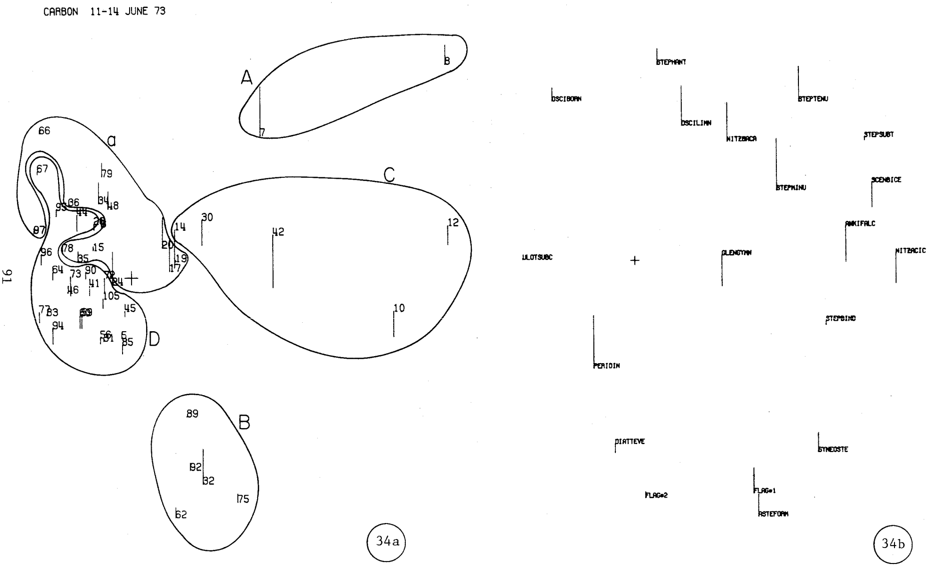


FIG. 34. Ordination of stations and taxa for cruise #10 based on PCA of estimated carbon density. See also Fig. 36a and Table 26. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

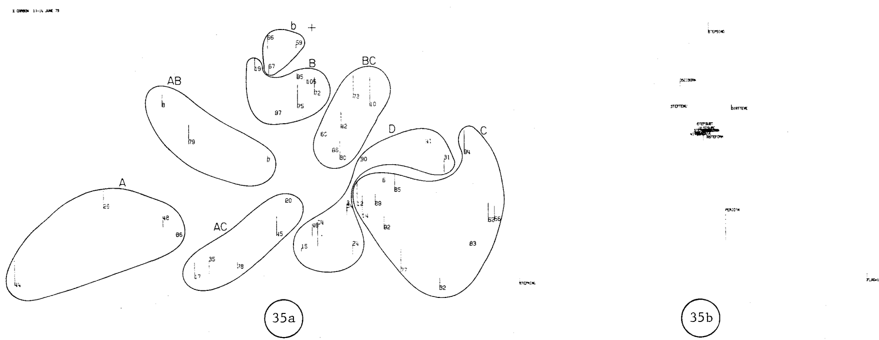


FIG. 35. Ordination of stations and taxa for cruise #10 based on PCA of estimated % carbon density. See also Fig. 36b and Table 27. (a) ordination of stations based on PCA scores (b) ordination of taxa based on PCA loadings

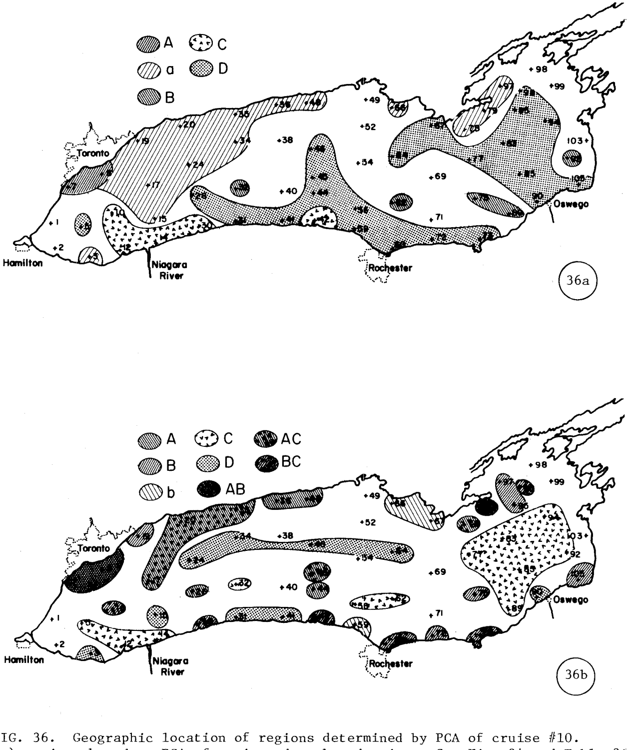


FIG. 36. Geographic location of regions determined by PCA of cruise #10.
(a) regions based on PCA of estimated carbon density. See Fig. 34 and Table 26.
(b) regions based on PCA of estimated % carbon density. See Fig. 35 and Table 27.

TABLE 26. Mean values of estimated taxa carbon density by regions determined in PCA of cruise #10. See Figs. 34, 36a.

11-14 Jun 73	Grand 48	A 2	a 14	B 5	C 5	D 22	F-stat
Ankistrodesmus falcatus	.179	.039	.048	.073	1.264	.053	1.824
	2.719	.055	.059	.096	.883	.069	5.8,4
Ankistrodesmus setigerus	.003	.000	.006	.000	.000	.004	.023
	.082	.000	.022	.000	.000	.018	186.4,1
Asterionella formosa	6.204	7.294	3.926	21.078	4.427	4.579	7.359 *
	28.297	3.379	3.210	5.913	5.610	3.774	5.7,4
Cryptomonas erosa	.967	.000	.972	.000	6.245	.073	2.689
	13.612	.000	1.637	.000	5.013	.341	24.9,2
Glenodinium, Gymnodinium spp.	1.033	1.104	.703	1.124	3.413	.675	.913
	8.634	.710	.779	.969	3.213	.780	5.7,4
Diatoma tenue var. elongatum	4.708	2.180	1.699	13.952	1.769	5.419	3.256
	26.284	1.321	3.010	8.072	1.408	6.727	7.6,4
flagellate #1	27.766	24.118	22.077	68.892	35.878	20.527	2.353
	104.863	27.411	17.261	32.082	19.577	16.033	5.5,4
flagellate #2	.885	.132	.522	2.397	.423	.945	6.729 **
	3.877	.187	.497	.974	.326	.827	8.3,4
Gloeocystis planctonica	.469	.082	.250	.514	.651	.593	3.010
	2.187	.116	.494	.532	.473	.693	10.6,4
Lagerheimia ciliata	.000						
	.000						
Melosira islandica	1.459	.126	1.601	2.821	.000	1.511	2.354
	17.631	.178	4.636	3.423	.000	2.559	21.6,3
Nitzschia acicularis	.095	.340	.012	.170	.386	.041	6.508 *
	.624	.321	.033	.161	.157	.061	5.3,4
Nitzschia bacata	.771	2.659	1.300	.491	.409	.409	6.090 *
	5.728	.579	1.468	.657	.501	.437	5.7,4
Nitzschia dissipata	.049	.052	.071	.021	.052	.040	.724
	.365	.074	.097	.029	.052	.066	6.1,4
Nitzschia sp. #2	.622	.785	.673	.838	.209	.619	.662
	3.664	1.110	.857	.951	.468	.978	5.9,4
Oocystis spp.	.112	1.058	.000	.000	.548	.023	.596
	2.116	1.496	.000	.000	.795	.106	6.4,2
Oscillatoria bornetii	2.708	5.257	5.189	.191	.382	1.999	1.841
	25.808	7.435	7.542	.427	.855	4.926	6.2,4
Oscillatoria limnetica	8.950	18.780	12.869	5.567	9.308	6.251	3.181
	29.479	15.131	6.326	2.305	5.050	3.560	5.7,4
Phacotus lenticularis	.000						
	.000						
Peridinium spp.	12.868	10.427	18.938	21.052	.993	10.065	11.224 **
	54.615	14.745	13.382	9.457	1.404	9.692	5.9,4
Scenedesmus bicellularis	.401	.836	.200	.140	2.083	.167	3.690
	4.640	.267	.166	.177	1.529	.209	5.6,4
S. quadricauda var. quadrispina	.019	.000	.000	.000	.000	.042	.000
	.611	.000	.000	.000	.000	.143	0,0
Staurastrum paradoxum	.000						
	.000						
Stephanodiscus alpinus	.005	.000	.000	.000	.044	.000	.000
	.221	.000	.000	.000	.099	.000	0,0
Stephanodiscus binderanus	8.113	17.653	5.439	14.547	17.057	5.452	1.373
	57.212	7.219	7.471	21.070	22.950	5.223	5.4,4
Stephanodiscus hantzschii	.500	1.209	.719	.158	.466	.382	28.932 **
	2.111	.093	.614	.141	.387	.473	9.5,4
Stephanodiscus minutus	26.330	66.358	39.708	33.225	22.460	13.491	91.308 **
	100.790	2.756	22.346	11.370	11.598	7.328	8.2,4
Stephanodiscus subtilis	1.401	11.266	.441	.833	4.060	.639	11.191 **
	20.748	13.409	.729	.594	.983	.595	5.5,4
Stephanodiscus tenuis	6.256	56.212	5.896	4.006	3.715	3.032	44.546 **
	59.604	4.797	4.540	2.766	2.382	2.874	5.8,4
Surirella angusta	.053	.000	.061	.000	.000	.078	.024
	.569	.000	.121	.000	.000	.200	271.7,1
Synedra ostenfeldii	.174	.244	.122	.585	.228	.096	5.418 *
	.894	.115	.138	.202	.226	.134	5.3,4
Ulothrix subconstricta	.725	.000	.866	.925	.000	.821	.033
	6.610	.000	1.782	.277	.000	1.240	70.0,2
total algal carbon	124.270	234.059	135.945	198.807	128.540	88.950	15.682
	260.417	37.276	42.960	29.540	60.019	26.729	5.6,4

TABLE 27. Mean values of estimated taxa % carbon density by regions determined in PCA of cruise #10. See Figs. 35, 36b.

11-14 Jun 73	Grand 48	A 4	AB 3	B 6	b 3	C 12	AC 5	BC 6	D 9	F-stat
Ankistrodesmus falcatus	.151 1.469	.000 .000	.012 .022	.080 .067	.057 .049	.267 .561	.063 .104	.420 .486	.059 .082	1.564 16.9,6
Ankistrodesmus setigerus	.004 .109	.000 .000	.000 .000	.018 .043	.000 .000	.000 .000	.000 .000	.000 .000	.008 .023	.037 145.6,1
Asterionella formosa	4.662 14.244	2.854 2.664	3.714 1.351	6.897 4.508	1.983 .611	6.384 4.239	4.536 5.512	3.754 2.562	3.562 2.557	2.459 13.4,7
Cryptomonas erosa	.902 13.840	.720 .854	.000 .000	.000 .000	.000 .000	.689 1.816	1.490 1.446	3.941 6.115	.116 .347	1.120 25.8,4
Glenodinium, Gymnodinium spp.	.932 8.779	.075 .150	.302 .309	.199 .219	1.120 .383	1.040 1.546	.378 .391	2.267 3.407	1.223 .885	4.100 * 12.4,7
Diatoma tenue var. elongatum	4.066 26.274	.000 .000	1.278 .722	6.754 6.101	1.776 1.548	7.587 7.332	.731 1.088	6.158 6.097	1.536 2.093	2.185 16.5,6
flagellate #1	21.070 46.259	5.212 4.875	8.959 7.271	10.259 4.858	3.119 2.757	37.602 7.120	19.443 4.164	20.972 4.394	24.275 3.777	27.193 ** 12.0,7
flagellate #2	.792 5.371	.033 .066	.182 .232	.891 1.030	.944 1.047	.999 .748	.459 .354	1.326 2.017	.770 .473	5.606 ** 11.7,7
Gloeocystis planctonica	.471 2.790	.348 .696	.049 .043	.711 1.084	.585 .591	.646 .866	.032 .047	.822 .500	.247 .232	3.517 * 12.6,7
Lagerheimia ciliata	.000 .000									
Melosira islandica	1.573 17.650	7.673 8.794	.199 .247	3.872 6.639	.705 1.221	.534 1.040	1.536 2.575	.388 .950	.276 .543	.778 12.4,7
Nitzschia acicularis	.078 .462	.046 .066	.106 .147	.091 .074	.000 .000	.099 .136	.026 .059	.223 .182	.004 .012	2.804 13.6,6
Nitzschia bacata	.640 3.584	1.927 1.125	.995 .432	.617 .777	.437 .567	.299 .251	1.278 1.301	.299 .240	.362 .415	1.935 10.9,7
Nitzschia dissipata	.052 .456	.234 .218	.090 .122	.042 .065	.015 .026	.019 .027	.027 .045	.067 .052	.027 .039	1.014 11.2,7
Nitzschia sp. #2	.611 4.172	1.532 1.356	.640 .659	.630 .379	1.391 2.409	.097 .269	.748 .704	.798 .915	.406 1.057	2.058 10.6,7
Oocystis spp.	.071 1.019	.000 .000	.340 .588	.000 .000	.174 .302	.000 .000	.300 .000	.314 .488	.000 .000	.046 35.9,2
Oscillatoria bornetii	2.343 23.072	2.506 2.893	4.552 4.830	3.136 4.182	15.967 11.945	.686 1.917	1.159 1.222	.853 1.457	.325 .541	1.479 10.6,7
Oscillatoria limnetica	7.395 19.022	4.349 4.391	7.015 3.853	5.791 2.716	11.159 5.695	6.113 3.121	6.580 4.769	6.987 2.727	11.147 4.689	1.288 11.4,7
Phacotus lenticularis	.030 .000									
Peridinium spp.	10.164 31.316	8.280 8.763	2.669 4.623	5.075 1.574	6.699 1.372	8.792 6.133	14.164 8.279	4.410 5.677	21.490 5.170	9.540 ** 12.3,7
Scenedesmus bicellularis	.349 2.508	.845 .845	.269 .151	.164 .117	.231 .120	.395 .796	.102 .091	.781 .558	.106 .120	1.865 11.9,7
S. quadricauda var. quadrispina	.024 .665	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.127 .257	.000 0,0
Staurastrum paradoxum	.000 .000									
Stephanodiscus alpinus	.005 .236	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.039 .096	.000 .000	.000 0,0
Stephanodiscus binderanus	6.071 28.590	.239 .478	9.004 3.628	12.837 9.961	6.590 3.490	3.414 3.003	3.339 3.635	12.411 10.345	3.835 5.165	6.372 ** 11.5,7
Stephanodiscus hantzschii	.455 2.183	.639 .584	.794 .471	.723 .735	.591 .547	.174 .162	.216 .237	.580 .798	.459 .342	1.715 10.6,7
Stephanodiscus minutus	21.471 69.407	50.145 13.221	31.115 5.707	16.769 3.890	11.061 3.927	14.736 6.162	37.020 7.623	15.428 1.821	16.486 8.518	9.578 ** 11.4,7
Stephanodiscus subtilis	1.042 9.989	.098 .195	3.558 5.580	.714 .778	.390 .676	1.147 1.065	.056 .124	2.132 1.976	.739 .647	3.383 * 11.6,7
Stephanodiscus tenuis	4.486 28.697	6.235 4.871	16.902 13.799	5.658 3.937	3.187 3.221	2.091 1.651	1.835 .967	3.000 1.591	4.878 3.417	1.860 11.2,7
Surirella angusta	.076 1.410	.676 .643	.000 .000	.046 .112	.000 .000	.000 .000	.056 .126	.000 .000	.041 .123	.495 34.6,3
Synedra ostenfeldii	.127 .472	.102 .135	.090 .058	.183 .162	.154 .267	.170 .158	.174 .117	.095 .080	.040 .069	1.332 11.7,7
Ulothrix subconstricta	.672 5.031	.000 .000	.323 .560	1.664 1.833	1.640 1.742	.899 1.304	.301 .673	.582 1.426	.067 .200	1.389 12.6,6
total algal carbon	124.270 260.417	81.596 41.603	209.034 50.729	121.205 48.234	99.016 13.438	139.078 53.766	135.602 55.423	96.505 53.719	117.915 49.622	2.257 12.9,7

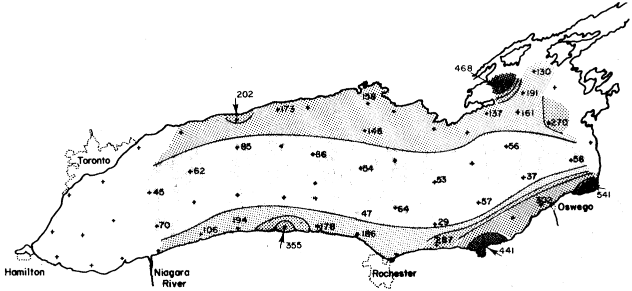


FIG. 37. Distribution of total estimated algal carbon for cruise #1. Numbers show estimated carbon values in μgC/l. Contour interval is 100 μgC/l.

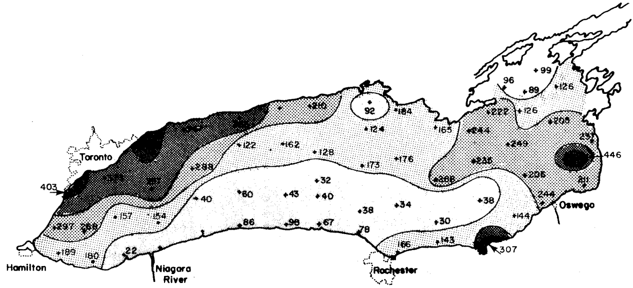


FIG. 38. Distribution of total estimated algal carbon for cruise #2. Numbers show estimated carbon values in μgC/l. Contour interval is 100 μgC/l.

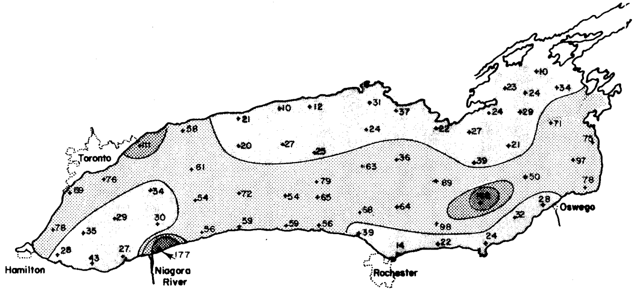


FIG. 39. Distribution of total estimated algal carbon for cruise #3. Numbers show estimated carbon values in µgC/1. Contour interval is 50 µgC/1.

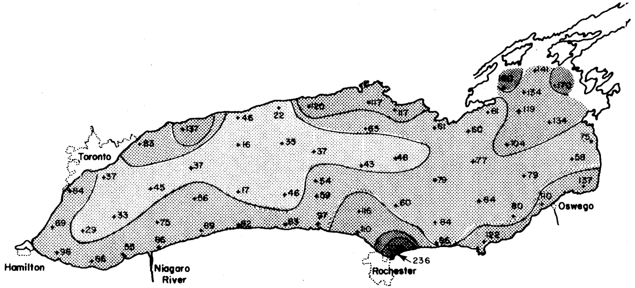


FIG. 40. Distribution of total estimated algal carbon for cruise #4. Numbers show estimated carbon values in µgC/1. Contour interval is 50 µgC/1.

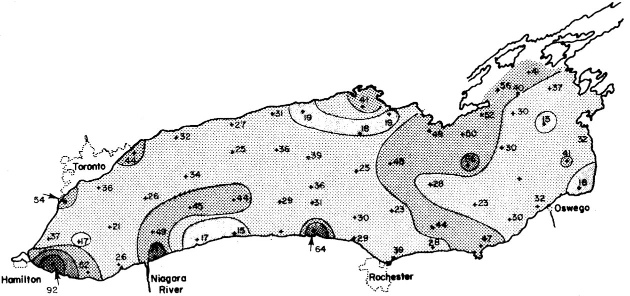


FIG. 41. Distribution of total estimated algal carbon for cruise #5. Numbers show estimated carbon values in μgC/1. Contour interval is 20 μgC/1.

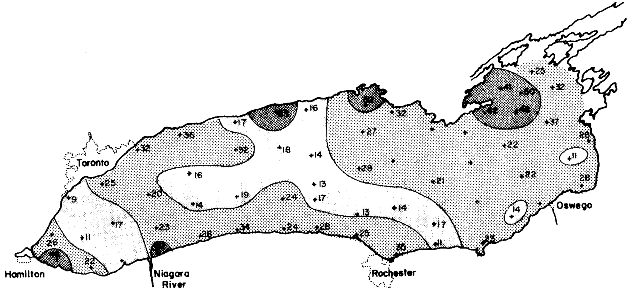


FIG. 42. Distribution of total estimated algal carbon for cruise #6. Numbers show estimated carbon values in μgC/1. Contour interval is 20 μgC/1.

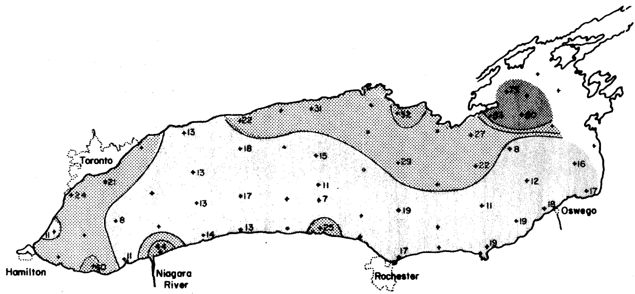


FIG. 43. Distribution of total estimated algal carbon for cruise #7. Numbers show estimated carbon values in μgC/l. Contour interval is 20 μgC/l.

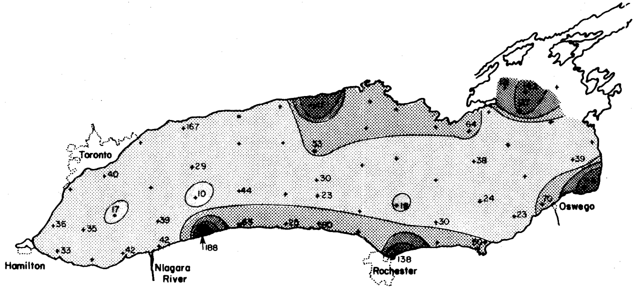


FIG. 44. Distribution of total estimated algal carbon for cruise #8. Numbers show estimated carbon values in μgC/l. Contour interval is 20 μgC/l.

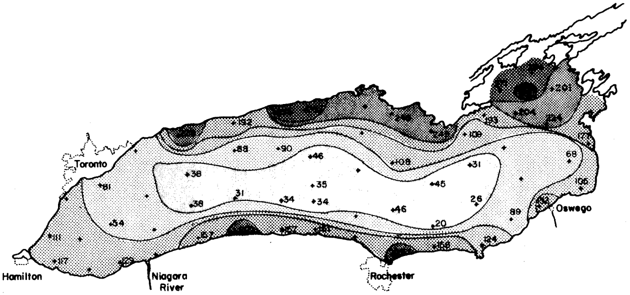


FIG. 45. Distribution of total estimated algal carbon for cruise #9. Numbers show estimated carbon values in μgC/l. Contour interval is 50 μgC/l.

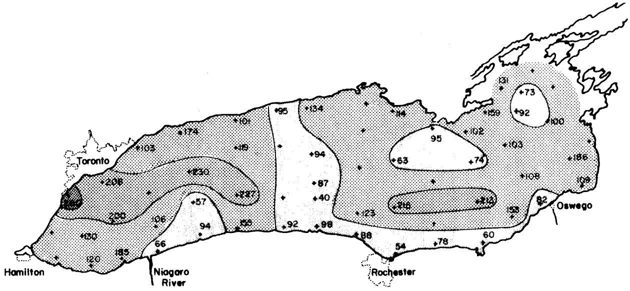


FIG. 46. Distribution of total estimated algal carbon for cruise #10. Numbers show estimated carbon values in μgC/l. Contour interval is 100 μgC/l.

TEMPERATURE AND ALGAL DENSITY

In order to typify the apparent temperature preferences of some of the more abundant species in Lake Ontario, their pattern of abundance relative to temperature has been parameterized (Table 28). The procedure used in this analysis is the same used by Stoermer and Ladewski (1976) in studying Lake Michigan populations. As might be expected, many of the more abundant diatoms have their apparent temperature optima in the lower range found in Lake Ontario. Notable exceptions to this are *Coscinodiscus subsalsa*, a species generally considered tolerant of extremely eutrophied conditions, and the eurytopic dominants *Fragilaria crotonensis* and *Diatoma tenue* var. *elongatum*. Conversely, assemblages occurring at the higher temperatures encountered in Lake Ontario tend to be dominated by green and blue-green algae. Notable exceptions to this generality are the exceptional spring bloom of *Scenedesmus bicellularis* at low temperatures and the persistance of *Anacystis cyanea*, *Gomphosphaeria aponina*, and *G. wichurae* into the fall and early winter cooling season. Although the persistence of other *Anacystis* species into the fall has been previously noted in the Great Lakes (Schelske et al., 1976) the behavior of *A. cyanea* in Lake Ontario is somewhat puzzling since it is usually considered a summer bloom form. Cases are known (Wildman et al.,1975), however, of the survival of summer blooming blue-green populations surviving into the winter in eutrophic lakes.

TABLE 28. Temperature parameters for taxa. Taxa for which pattern of abundance relative to temperature is approximately Gaussian. Estimates given are based on parameterization as discussed in text. Tm = predicted temperature (°C) of maximum absolute (cells/ml) and relative (%) abundance. S = parameter estimating temperature tolerance of taxa. M = predicted level of absolute (cells/ml) and relative (%) abundance at optimal temperature in Lake Ontario. Fixed = number of parameters fixed in analysis. See text for further explanation.

Species or Category	Tm(°C)		S(°C)		M		Fixed	
	Abso abun	Rel abun	Abso abun	Rel abun	Abso abun	Rel abun	Abso abun	Rel abun
Stephanodiscus alpinus	-0.3	-1.3	5.2	4.6	166.	27.6	1	1
Stephanodiscus hantzschii	1.1	2.6	8.0	18.0	911.	39.8	2	2
Nitzschia dissipata	2.6	7.3	11.7	9.4	39.8	5.0	2	0
Surirella angusta	3.5	2.8	3.4	2.2	41.9	6.1	0	2
Nitzschia filiformis	3.9	2.2	1.7	1.3	23.2	2.8	0	0
Stephanodiscus niagarae	3.9	6.6	3.2	5.1	35.6	10.0	1	2
Scenedesmus quadricauda v. *maximus*	4.1	12.8	1.1	6.2	44.0	5.3	0	0
Nitzschia sp. #2	4.3	2.6	1.6	3.1	78.6	3.9	0	0
Stephanodiscus tenuis	5.1	0.5	4.7	6.9	1340.	53.4	0	0
Nitzschia bacata	5.9	1.2	4.5	10.6	70.6	5.5	0	2
Tabellaria fenestrata	6.6	6.8	8.0	5.9	106.	18.3	0	0
Asterionella formosa	6.9	10.0	5.3	8.1	892.	53.4	0	0
Gomphosphaeria wichurae	7.0	4.2	2.1	5.8	1280	84.9	0	0
Cryptomonas erosa	7.3	6.7	3.0	4.0	291.	7.0	1	0
Anacystis cyanea	7.6	5.8	5.3	3.7	496.	70.3	0	0
Melosira islandica	8.2	7.2	4.8	5.1	373.	19.0	0	0
Peridinium spp.	8.2	21.8	0.6	13.2	677.	20.5	0	2
Synedra ostenfeldii	8.3	3.1	4.5	0.2	32.6	3.8	0	2
Gomphosphaeria aponina	8.5	8.5	1.2	1.2	524.	54.2	1	1
flagellate #2	8.7	8.6	4.2	4.3	214.	15.3	0	0
Stephanodiscus binderanus	8.7	9.7	4.1	4.9	3188	59.0	1	0
Stephanodiscus minutus	8.8	9.6	6.1	7.3	1137	54.5	1	0
Melosira granulata	8.9	3.5	4.4	4.4	52.	6.8	0	0
Scenedesmus bicellularis	8.9	7.6	3.1	3.5	1707	73.2	0	0
Nitzschia holsatica	9.4	5.4	3.6	4.9	112.7	12.4	0	0
Fragilaria capucina	9.4	8.1	2.6	1.4	817.	84.8	1	0
Pediastrum duplex	10.2	10.2	0.3	0.4	64.8	7.1	0	0
Diatoma tenue	10.3	8.2	5.2	7.6	83.8	3.2	1	1
Scenedesmus quadricauda	10.3	9.3	3.9	2.6	26.1	4.7	0	1
Glenodinium spp. and *Gymnodinium* spp.	11.5	14.2	7.5	4.4	115.	32.5	0	0
Coccomyxa coccoides	11.8	12.2	1.0	1.5	2094.	26.5	1	0
Nitzschia acicularis	12.4	10.6	6.3	9.6	51.9	2.0	0	0
Cyclotella meneghiniana	12.7	11.1	3.7	6.5	30.2	1.1	0	0
Oscillatoria limnetica	12.7	18.3	3.9	7.9	389.	26.5	0	2
flagellate #1	13.0	12.5	1.9	5.8	5705	85.3	1	0
Ankistrodesmus falcatus	13.0	14.0	5.4	4.8	451.	21.1	0	1
Diatoma tenue var. *elongatum*	13.3	18.9	4.2	1.1	532.	39.1	0	0
Anacystis incerta	13.5	14.8	5.2	5.8	1194	68.0	1	1
Oscillatoria bornetii	15.0	8.9	2.8	6.0	90.1	6.5	1	1
Scenedesmus quadricauda v. *longispina*	15.8	10.1	5.0	6.8	80.0	6.2	0	0
Crucigenia quadrata	16.8	16.2	2.7	2.4	69.8	4.0	0	0
Gloeocystis sp. #1	16.9	17.3	1.9	2.0	430.	28.7	0	0
Coelastrum microporum	17.3	16.5	3.8	7.1	616.	35.6	0	2
Scenedesmus quadricauda v. *quadrispina*	19.0	21.1	6.4	10.2	100.	8.8	0	2
Anabaena flos-aquae	19.4	19.1	1.4	1.5	660.	42.5	0	0
Gomphosphaeria lacustris	19.9	13.9	7.4	3.4	628.	56.3	2	1
Fragilaria crotonensis	20.0	17.4	10.8	9.2	766.	47.4	2	1
Ankistrodesmus setigerus	20.4	20.3	0.5	1.2	76.8	7.9	0	0
Coscinodiscus subsalsa	20.6	7.4	8.6	3.6	31.4	5.0	2	0
Botryococcus braunii	20.7	21.2	0.7	1.3	1047	34.2	1	1
Eudorina elegans	20.7	21.4	1.4	6.7	345.	25.8	2	1
Pediastrum glanduliferum	21.0	21.2	1.0	1.1	448.	21.5	0	0
Anabaena variabilis	21.5	15.8	0.6	2.6	1361	18.9	1	1
Borodinella sp. #1	21.7	17.1	10.7	5.2	134.	11.5	2	1
Staurastrum paradoxum	21.9	21.6	1.6	13.3	27.3	4.3	0	2
Lagergeimia ciliata	22.2	22.2	4.5	2.4	50.3	5.1	2	2
Phacotus lenticularis	22.8	23.7	4.2	8.0	250.	30.9	0	2

TABLE 29. Temperature parameters for taxa with non-Gaussian characteristics. Taxa for which pattern of abundance relative to temperature is apparently not Gaussian. Estimates given are based on best fit obtainable with parameterization procedure used. Parameters labeled as in Table 28.

Species or Category	Tm(°C) Abso abun	Tm(°C) Rel abun	S(°C) Abso abun	S(°C) Rel abun	M Abso abun	M Rel abun	Fixed Abso abun	Fixed Rel abun
Ulothrix sp. #1	7.9	--	4.4	--	466.	--	0	-
Stephanodiscus subtilis	10.7	--	8.4	--	1609	--	0	-
Dinobryon sociale	--	15.2	--	1.6	--	5.1	-	0
Pediastrum simplex	15.3	--	5.6	--	193.	--	1	-
Agmenellum thermale	--	15.9	--	0.5	--	18.2	-	1
Tetraedron minimum	--	16.0	--	7.2	--	1.3	-	1
Gloeocystis planctonica	--	21.1	--	7.2	--	55.7	-	0
Ulothrix subconstricta	21.1	--	0.5	--	2039	--	0	-
Oocystis spp.	21.2	--	1.5	--	333.	--	0	-

CONCLUSIONS

Our results show that there is no consistant overall pattern of phytoplankton distribution in the near-surface waters of Lake Ontario. There is generally poor correspondence between the patterns shown on various cruises, and particular stations are not consistently associated with any distinct floristic association.

One might expect, *a priori*, that distinctive floristic associations would be found at stations adjacent to major sources. This expectation is realized to a limited degree. On several cruises, stations near Toronto, Hamilton, Rochester, and the Niagara have similar associations, different from the rest of the lake. These trends are not as consistent as might be expected, either in the degree of distinctiveness of the floristic associations found or in the areal extent of the regions with common associations. This result is somewhat surprising in light of much more easily interpreted patterns found in regions of the Great Lakes which receive less loading (Schelske et al., 1976). One factor that probably contributes to this is the fact that stations directly immediate to sources were not available in the present analysis. If particular taxa or groups of taxa are favored by particular inputs, their dominance might reasonably be expected to be greatest immediately adjacent to the source. All of the stations considered in this study are at some distance from sources, and hence the clarity of any such relationships may be partially masked by the effects of physical mixing or losses due to predation or sinking.

The other very striking difference between the present study and similar attempts to characterize areas of the Great Lakes on the basis of their phytoplankton associations is the total lack of species which are considered indicative of oligotrophic conditions in Lake Ontario. All of the taxa abundant enough to be considered in the PCA are tolerant of eutrophic conditions. This, in a sense, has the effect of limiting the scale of our analysis since in Lake Ontario, unlike the upper lakes, one end of the trophic spectrum has essentially been eliminated. It may well be that in a system as severely forced as Lake Ontario, phytoplankton distribution patterns are mainly reflective of transient physical conditions or biotic factors.

It should also be remembered that the data considered in this report are restricted to the near surface waters. Since there may be a strong vertical zonation of phytoplankton population abundance during periods of stratification, the patterns are not necessarily reflective of the total distribution of any given taxon. This problem is particularly severe if cases exist where populations developed at depth are transported to the near surface waters either actively or passively. Events, such as upwellings, which result in passive vertical transport would reasonably be expected to be of the time and space scales which would be resolved by the present analysis. Active vertical migration of particular populations could be a seriously complicating factor since they are most likely cued by light level and the cruises were run on a 24 hr basis. The fact that stations on adjacent lines are differently grouped suggests that this may be a factor, although the apparent cases we have inspected indicate this is not likely. Direct experimental verification would be needed to evaluate this effect.

It is also apparent that a finer time scale in sampling would be desirable in a rapidly changing system such as Lake Ontario. It is highly probable that

the population maxima of some of the more important phytoplankton taxa were missed because of the long intervals between sampling. This is especially true of the late summer - early fall period. Why Lake Ontario during IFYGL apparently underwent change more rapidly than is usual in the upper Great Lakes is not clear, although part of the difference may be due to the timing of the IFYGL sampling during a highly atypical year in terms of meteorological conditions.

The distribution of total near-surface algal biomass is also unusual when compared with the upper Great Lakes. In southern Lake Michigan (Ladewski and Stoermer, 1973; Stoermer unpublished data) and Lake Huron (Stoermer, in prep.) it is normal for highest standing crops to occur inshore and lower standing crops offshore. While this is often true for Lake Ontario, there are many exceptions (e.g. Figs. 39, 41, 46).

The results of this study do clearly show that the patterns of phytoplankton abundance and composition present in Lake Ontario during IFYGL are unlikely to be captured by any arbitrarily composed segmentation scheme. According to our analysis there are literally no station pairs which could be assumed not to have significantly different phytoplankton assemblages at some time during the IFYGL sampling.

Nevertheless, there do appear to be some general patterns of algal distribution. A region of stations in the southwestern part of the lake often group together (e.g. cruises 2, 4, 5, 8-10). This region is often characterized further by either very low total algal density (e.g. cruise 2) or very high density (e.g. cruises 3, 5) especially near the mouth of the Niagara River which is apparently the main influence on this region.

Another region which shows itself most strongly in spring is located in the northwestern part of the lake near Toronto (e.g. cruise 2, 10). Spring diatom densities are particularly high here.

Stations of the northeastern corner tend to group together (e.g. cruises 2, 4, 6-8), although the size and exact location of the group varies considerably. Usually total algal density shows an increase toward the northeastern corner.

There is an apparent effect by Rochester (e.g. cruise 4), where total densities are often high and algal communities often unique. Mexico Bay, near Oswego, also often has high total densities (e.g. cruise 2) and its own community.

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